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Enclosed Superstructures for Light and Sound Buoys

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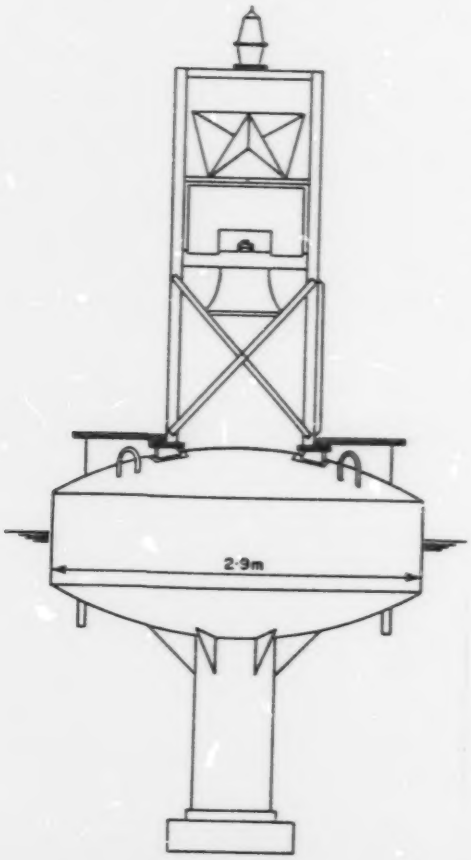

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Un sommaire en français de ce rapport est inclus avant la Table des matières.

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16. Abstract

This report discusses the development of two prototype enclosed superstructures for the 2.9 m light and sound buoys used by the Canadian Coast Guard as floating aids-to-navigation.

It discusses the functional and operational requirements for navigation buoy superstructures and the advantages of enclosing superstructures. It details the project activities, which include concept development, detail design and prototype fabrication. The completed prototype designs are described with summary statistics.

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16. Résumé

Ce rapport rend compte des travaux qui ont mené à la réalisation de deux prototypes de carénages pour les bouées lumineuses et sonores de 2,9 m de diamètre, utilisées par la Garde côtière canadienne comme aides flottantes à la navigation.

Il expose les exigences opérationnelles et fonctionnelles auxquelles doivent répondre ces carénages et les avantages qu'ils offrent. Il donne un compte rendu détaillé des tâches exécutées dans le cadre du projet, soit, entre autres, la définition de concepts de carénage, l'étude détaillée de ces concepts et la réalisation des prototypes. Il présente finalement une description des prototypes, ainsi que des statistiques sommaires.

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PROJECT TEAM

The project team included:

Ron Cunningham, P. Eng.

Philip Huntley, Mechanical Technologist

SUMMARY

The Canadian Coast Guard maintains over 13 000 floating aids-to-navigation. The largest of these are the 2.9 m diameter light and sound signal buoys placed in coastal waters. There were 583 light and sound buoys in Canada in 1990.

An open frame superstructure supports the navigation signals. Short-range signals typically include: light; radar reflector; sound signal (bell or whistle); and coloured surface area or daymark.

Development program for smaller light buoys show that enclosed superstructures may perform better than open frame designs. Benefits include reduced maintenance cost and improved icing characteristics. Ice accretion or buildup can be a problem during winter months, particularly on the Canadian east coast.

This report discusses the development of two prototype enclosed superstructures for 2.9 m light and sound buoys, one for each bell and whistle buoy type. The project phases included requirements definition, concept development and detailed design. Prototypes were built, delivered and installed for operational tests.

The significant findings from this project include:

- buoy structures should have a long design lifetime—buoy hull life exceeding fifty years is common;
- steel is the most appropriate structural material for retrofitting to existing 2.9 m steel buoy hulls;
- the primary design challenge in enclosed superstructure development is the balancing of tradeoffs due to conflicting requirements.

Improvements over the present designs are:

- higher strength;
- lower mass, for the whistle buoy;
- reduced centre of gravity, improving stability;
- greater daymark area, improving visibility;
- watertight chambers in the base of the structures, providing a dry area for future incorporation of electronic system and batteries for photovoltaic power system;

- better ice accretion properties, particularly for the whistle buoy prototype that has an outer cover of Surlyn™ plastic; and

- improved ergonomics while servicing the signal light.

Disadvantages include:

- higher fabrication cost, which should be offset through longer life and reduced maintenance cost;

- vulnerability to damage of the handles and ladders that must be provided for service.

Further development should continue following a period of operational testing. The two designs incorporate different approaches in many areas. The best features from each superstructure should be consolidated. The resulting unified design would be suitable for both sound signal types. There is potential for significant long-term cost savings through reduced maintenance requirements.

SOMMAIRE

La Garde côtière canadienne exploite plus de 13 000 aides flottantes à la navigation. Les plus grosses sont des bouées lumineuses et sonores de 2,9 m de diamètre qui balisent les eaux côtières. En 1990, les eaux canadiennes comptaient 583 bouées lumineuses et sonores.

Les dispositifs de signalisation à courte portée - fanaux, réflecteurs radar, signaux sonores (cloche ou sifflet) et surfaces colorées ou marques de jour - sont montés dans une superstructure ouverte.

Des recherches effectuées sur des bouées lumineuses de faible diamètre montrent que les bouées carénées à leur partie supérieure offrent un meilleur rendement que les bouées non carénées. Le carénage a notamment comme avantages de réduire le coût d'entretien des bouées et d'améliorer leur résistance au givrage. Or, l'accumulation de givre peut poser un problème durant les mois d'hiver, en particulier sur la côte est du Canada.

Ce rapport rend compte des travaux qui ont mené à la réalisation de deux prototypes de carénages pour des bouées lumineuses et sonores de 2,9 m de diamètre à cloche et à sifflet, en versions longue et courte. Une fois menées à bien les phases de définition des besoins, de définition et d'étude détaillée des concepts, les prototypes ont été réalisés, livrés et mouillées aux fins d'essais opérationnels.

Voici les principales conclusions auxquelles ont conduit ces travaux :

- les carénages des bouées doivent être conçus de manière à leur assurer une longue durée de vie -- les coques de bouée de plus de 50 ans sont en effet chose courante;

- l'acier est le meilleur matériau structural pour le rééquipement des bouées à coque d'acier existantes de 2,9 m de diamètre;

- le principal défi à relever dans l'élaboration des carénages est de réaliser un compromis entre des besoins divergents.

Améliorations par rapport aux modèles actuels :

- meilleure résistance;
- masse plus faible, pour la bouée sonore avec sifflet;
- centre de gravité plus bas, d'où une meilleure stabilité;
- marques de jour d'une plus grande superficie, d'où une meilleure visibilité;
- présence d'enceintes étanches à la base des carénages, pouvant constituer des réceptacles pour la mise en place éventuelle de systèmes électroniques et d'accumulateurs pour batteries solaires;
- meilleure résistance au givrage, en particulier dans le cas du prototype de bouée sonore à sifflet, recouverte de plastique Surlyn™;
- caractéristiques ergonomiques facilitant la maintenance des feux de signalisation.

Au nombre des inconvénients, citons :

- une augmentation des coûts de fabrication, laquelle devrait être compensée par une durée de vie prolongée et une diminution du coût d'entretien;

- des risques de dommages aux poignées et échelles d'entretien.

Il y aurait lieu de poursuivre le développement des prototypes au bout d'une certaine période d'essai opérationnel. Comme les deux modèles résultent d'approches différentes à de nombreux égards, il faudrait réaliser un carénage réunissant les caractéristiques optimales de chacun et qui pourrait convenir aux deux types de bouées sonores. Des économies importantes à long terme sont à escompter grâce à la diminution du coût d'entretien.

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1 INTRODUCTION

Mariners depend on a variety of system and devices for maritime navigation. Floating aids to navigation, or buoys, are particularly important for coastal navigation. The Canadian Coast Guard (CCG) places and maintains over 13 000 floating aids to navigation. The largest of these are the 2.9 m diameter light and sound signal buoys placed in coastal waters. Steel open frame superstructures are typically used to support the light and sound signals, which may be bells or whistles. Additional signals include a radar reflector and optional RACON and cardinal topmarks. In 1990 there were 583 light and sound buoys in Canadian waters. Figures 1 and 2 show 2.9 m bell and whistle buoys.

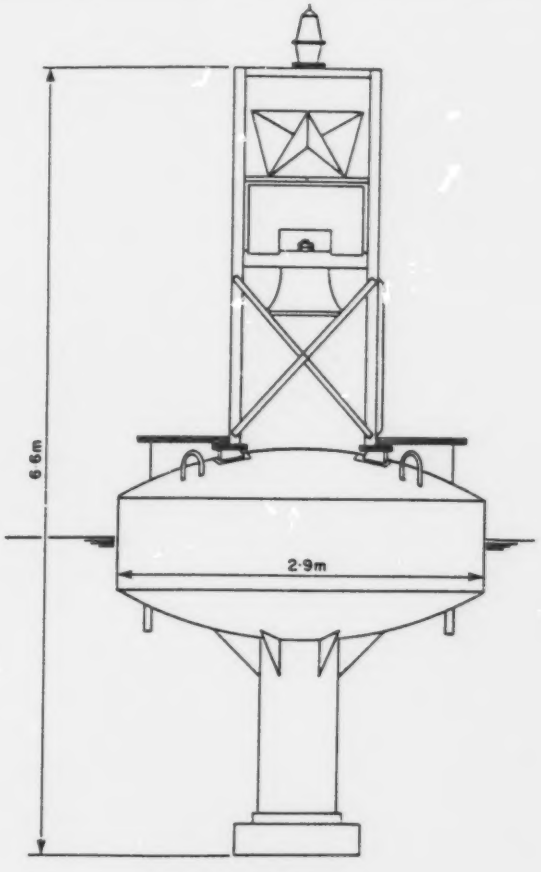

Figure 1 2.9 m Bell Buoy

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Previous work on smaller buoys has shown that there are advantages to using enclosed superstructures. Benefits include lower maintenance costs, reduced ice accumulation, and improved visibility. The objective of this project was to develop enclosed superstructures for 2.9 m bell buoy and whistle buoy hulls.

Ice accumulation on buoy structures exposed to freezing spray can be a problem in winter. Ice buildup, or accretion, decreases buoy stability. If the buoy leans or lists too much the plane of the signal light beam is tilted off-axis. The light can shine over an observor's head, or down into the water. Sound from the fog signals can be reduced by the ice coating. Also, mariners rely on navigation buoy colouring to indicate safe passage. Interpreting the buoy colour is difficult when part of the buoy structure is masked by ice.

Icing has not been a major problem, at least in recent years, in most regions. It is important that icing be considered, but from the proper perspective, as summarized by the following comment:

> While I agree that buoy icing is a serious problem when it occurs and tends to have a high profile, I think that it has been allowed to overshadow other important shortcomings in our present superstructure design. From the point of view of the quality of service our aids provide I believe that the overall effect of improved daymark visibility and improved appearance through easier maintenance will be greater than that accomplished by enhanced ice resistance.[1]

There have been some unsuccessful attempts to actively de-ice buoys. The energy requirements for de-icing heaters are too high to be feasible for buoy use. The National Research Council (NRC) tried to develop a buoy using the thermosiphon or heat pipe principle for active de-icing. The results of the program were promising at first. In trials using prototypes based on existing buoys, the superstructures were de-iced, but ice formation on the float was a problem. A new buoy design was developed for tests during the winter of 1975-76. There was insufficient heat transfer to remove significant ice buildup.

Improvements for passive de-icing have included fitting a 3 m discus buoy with a fully enclosed superstructure. This buoy was tested during 1982-83. Problem associated with this test program included poor transmission of sound from the bell, poor accessibility for servicing, inadequate footfall area for boarding at sea, and accumulation of water inside the structure. This experiment was not continued.

In another experiment, a standard 2.9 m bell buoy superstructure was covered with thin sheet steel and deployed in the Newfoundland region. Typically this region has the worst icing conditions. Unfortunately during the period of the test there were no icing events.

Four enclosed superstructure designs for the standard 1.8 m light buoy have been developed. These designs use steel, aluminum, polyethylene and a combination of aluminum and polyethylene in both cylindrical and square cross-section. These four prototype designs have evolved in parallel, beginning in 1983. Icing tests were carried out at the NRC cold chamber facility, followed by deployment in the Newfoundland region. There have been some structural

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[1] D. A. Long, internal Memorandum from CGAA-F/M to CGAA-R/M, March 22, 1985, File 8005-9

failures, but it appears that the new types of superstructure exhibit improved icing and ice removal characteristics, as well as improved visibility.

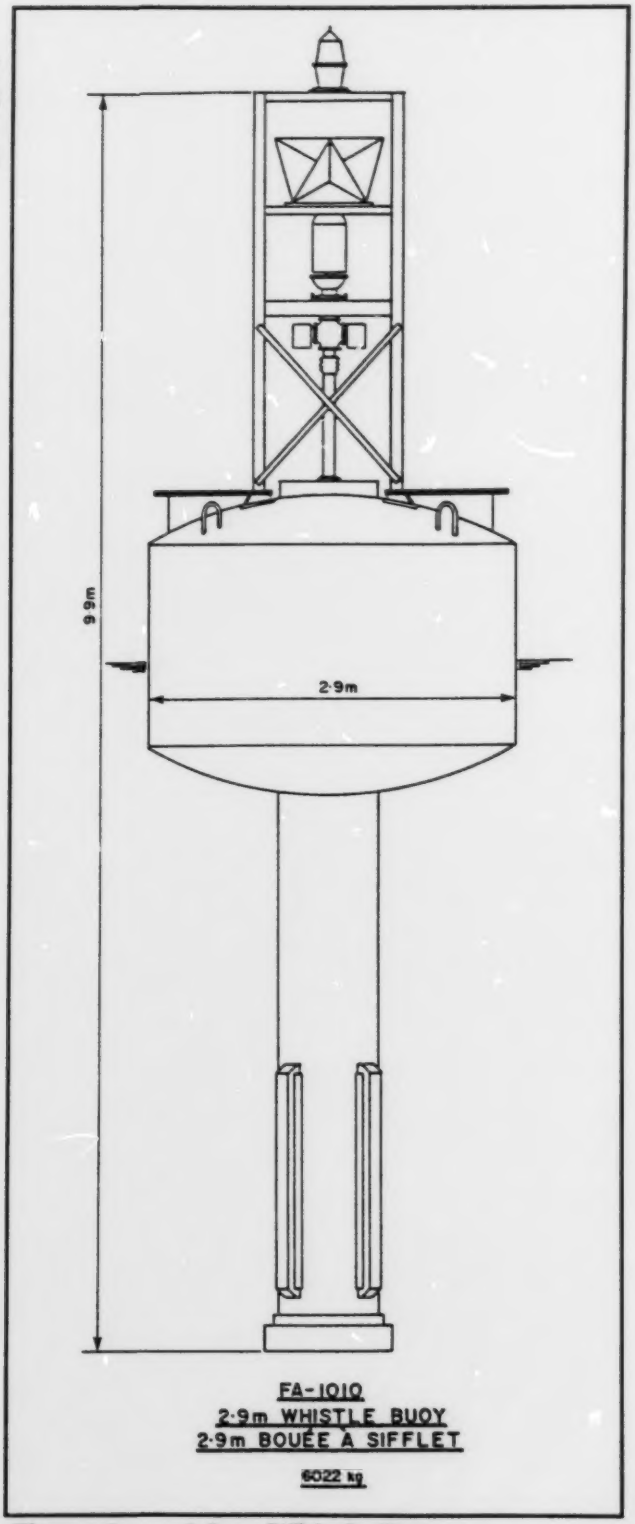

Figure 2 2.9 m Whistle Buoy

2 SUPERSTRUCTURE REQUIREMENTS

The superstructure requirements were established and refined through a series of meetings with Coast Guard personnel. The first meeting at the Dartmouth base was a round table discussion of superstructure issues and concerns. These individuals brought a wide range of experience to the meeting:

Dave Smith—Regional Aids Superintendent
Dan Veinot—District Engineer
John Fox—Mechanical Shop Foreman
Bruce Stirrat—Fleet Superintendent
Lionel MacDonald—Acting Yard Foreman
Steve Faulkner—Buoy Maintenance
Jim Bocking—Ships Representative

A second meeting was held with **Captain Hann**, **Paul Beesly** (First Officer) and **John Tobin** (Bosun) of the buoy tender **CCGV Edward Cornwallis**. Here the project team gathered information on buoy handling at sea. Also, we inspected the recovery equipment and working areas. A Coast Guard video supplied by **Ken Hamilton** of the Dartmouth base provided additional insight into buoy deployment and recovery.

The requirements were developed further during subsequent review meetings as the project progressed. The workplan for the project is included as Appendix A. The tasks were:

Task 1.	Project Initiation
Task 2.	Review Previous Work
Task 3.	Develop Conceptual Designs
Task 4.	Refine Selected Design Concepts
Task 5.	Detailed Design and Prototype Fabrication
Task 6.	Deliver Prototype Superstructures
Task 7.	Final Report

Superstructure requirements include both functional and operational types. Signal provision and serviceability are functional requirements. Operational requirements may be grouped as follows:

1. Safety of buoy handling personnel
    a. minimize recovery time by ensuring adequate access to pickup points
    b. provide adequate handholds and footfalls for working at sea
    c. provide sufficient structural strength to eliminate risk of failure during recovery
2. Safety of mariners
    a. improved endurance of structure
    b. improved signal characteristics, including during icing conditions

3. Fabrication and maintenance cost reduction

   a. longer maintenance period for routine maintenance
   b. lowered maintenance cost and complexity

The Work Statement lists these general guidelines:

   a. conformance to the general dimensions for light height above waterline as shown in drawings FA-1007 and FA-1010;

   b. incorporation of lower maintenance, lower ice accretion and increased day/night detectability characteristics compared to existing sound/light signal buoy designs; and

   c. direct mating with a typical 2.9 m buoy hull without the necessity to perform **major** modifications to the top of the hull (such as relocation of battery pockets).

Tradeoffs are often required to satisfy conflicting requirements. For example, a superstructure designed to fully minimize ice accretion might be a circular cylinder, perfectly smooth-sided, with no openings or external protuberances. However, such a structure could be dangerous to service at sea and may have poor sound transmission. If used on a bell buoy the cylinder, which would have to be quite large, would interfere with the battery wells. Superstructure design requires a balance between the requirements of initial cost, handling and operations, repair and maintenance, reliability, serviceability, ice accretion properties and signal quality.

2.1 Functional Requirements

2.1.1 Light

The light should not be blocked by any portion of the superstructure. The height of the lantern base above the waterline should be as stated in the requirements for the particular application. For the existing whistle and bell buoys, the lantern heights are as follows:

Whistle buoy lantern height: **4515 mm**

Bell buoy lantern height: **3921 mm***

* Since beginning the project, a new bell superstructure design having a light signal height of 3496 mm has been issued.

2.1.2 Sound Signals

The existing sound signals are completely mechanical. These signals are proven and reliable, and do not require battery power. Wave-actuated signals, particularly the bell buoys, are sometimes quiet when they are most needed, i.e. in heavy fog conditions. They could be replaced by electronic oscillator-driven signals, once cost, performance and reliability are improved. Therefore:

The enclosed superstructure design should be capable of incorporating new sound signal designs without requiring major modifications.

Maximum sound transmission will occur with the signal not enclosed, but it is possible to partially enclose the sound signal without excessive loss of signal range. In the future it may also be possible to develop a resonant ducted enclosure. This could be particularly effective when used with an electronic oscillator. To enable investigation and development of these concepts:

The prototype(s) should have the ability to fit removable panels around the sound signals.

Assuming that a fog signal has to be heard at one-half nautical mile above a background noise typical of a small diesel-powered vessel, with a detection probablility of 90%, then the sound pressure level required at 7.6 m is approximately 103 dB re 20 μPa. This value is relatively flat over the frequency range from 600 to 2400 Hz. For wave-actuated signals, measurement for comparison is difficult because the energy source fluctuates. The comparison can be made by measuring acoustic insertion loss of any panels or enclosures.

The maximum allowable acoustic insertion loss of any panels or enclosing structures should be 3 dB re 20 μPa.

2.1.3 Daymarks

The daytime visibility of the buoys is a function of visibility, daymark area and height, and brightness contrast ratio of the daymark pigment.

The colours used for navigation buoys must follow a standard established by the International Association of Lighthouse Authorities (IALA). Contrast ratio is fixed by the definition of these colours. For a given visibility and contrast ratio, the detection range will depend upon (1) projected daymark area, and (2) daymark height.

Daymark height is set by the signal light, which must be placed at the required height. Adding daymark area above the light creates problem such as interference with solar cells and topmarks. Therefore, daytime visibility will depend primarily on projected daymark area. There

will be some secondary improvements when using enclosed superstructures, e.g. covering the radar reflector with a coloured panel should increase effective contrast ratio. Simply stated:

The daytime visibility will be increased by increasing projected daymark area.

To give an example of required daymark area, assume that the daytime visibility requirements are as follows:

- buoy to be seen at three nautical miles when the transmissivity of the atmosphere is 0.50;
- the observer height is at least 4.5 m; and
- daylight sighting condition; clear sky; sky background.

Assuming an average effective contrast ratio of 2.6 (which may be high for standard IALA colours), then the required daymark area would be about two square metres[2].

2.1.4 Radar Reflector

Radar detection must be at least as good as the existing sound signal buoys. These are presently using a 610 mm octahedral reflector, an array of eight trihedral corner reflectors. The simplest way to do this is to enclose the existing radar reflector using a material nearly transparent to radar. Alternatives to the existing reflector would be desirable only if they reduce maintenance or improve performance.

The strength of return from a radar reflector is given in term of radar cross section, expressed in metres squared. For a trihedral corner reflector, radar cross section is given by the following formula[3]:

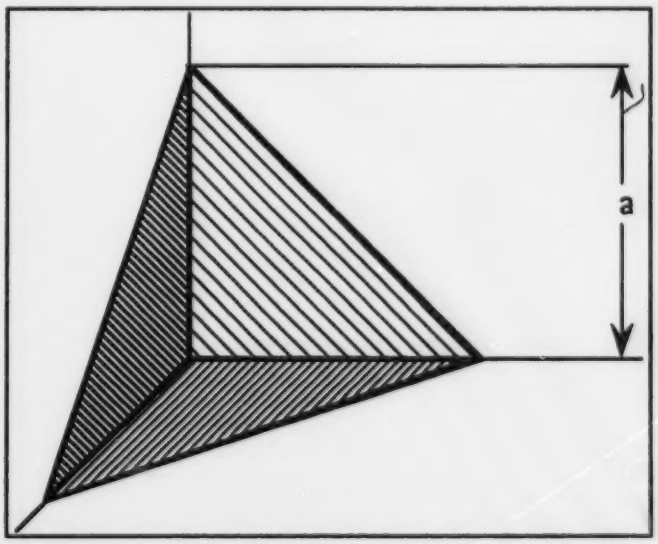

Figure 3 Trihedral Corner Radar Reflector

[2]Tindle, Ernst R. Lieutenant Commander, Proposals for the Marking of Oceanographic Buoys in International Waters and Some Sample Signal Design Solutions Based on these Proposals, MTS Buoy Technology-Transactions of the 1964 Buoy Technology Symposium.

[3]Skolnik, M.I., Radar Handbook, McGraw-Hill, p. 31-34.

$$\sigma = \frac{4\pi a^4}{3\lambda^2}$$

where σ is the RCS in m^2, a is the length of the edge joint in m, and λ is the radar wavelength in m.

Assume a 5 nautical mile radar range is desired with a 0.5 blip-scan ratio, or 50% probability of detection, for 3 cm (typical for "X" band) radar. A circular array of trihedral reflectors, mounted above the required minimum height for the desired range, should have a projected aperture perimeter of 30 to 60 times the radar wavelength. The existing 610 mm reflector has a projected perimeter of 60 x when oriented directly at the radar scanner, and decreasing as the reflector is angled away. In term of radar cross section (RCS) the 610 mm trihedral has an RCS of 162 m^2, or 22 dB re 1 m^2.

A typical wavelength for 'X' band radar is 3 cm, or .03 m. It is important to note that the edge length a is the length of the side containing the right angle, as shown in Figure 3. This is easily confused with the length of the outer edge, which is often used to define reflector size. For example, the 610 mm trihedral corner presently used has an edge length, a, of 432 mm.

The height above water at a reflector is an important factor because of the need to keep the reflector blip out of the sea return. For buoys, the effectiveness of the reflector varies as the fourth power of the height, within limits. For a five nautical mile radar range **the minimum reflector height should be 2.5 m**, and performance is improved as height increases.

2.1.5 Electrical Cabling

There are currently two approaches to the electrical cabling, one of which is applied at the Dartmouth base, and the other at the St. John's base. In Dartmouth, the cabling is fully protected from damage from ice chipping by steel conduit tubing and protective steel plates. In Newfoundland, where icing is typically worse, the cable is not run through conduits, and protective plating is not used. Instead, the emphasis is placed on educating the ship crew in safe de-icing procedures. The claimed advantage of this approach is that the cabling is readily accessible for rewiring at sea. Cut cables are not a problem. Newfoundland region stated they had experienced problem with cables becoming jammed in conduits which had rusted internally.

2.2 Operational Requirements

2.2.1 Handling

Once a buoy is safely in the water superstructure damage, other than corrosion, is unlikely. The Navigational Buoy Design Manual addresses the design criteria for superstructures while at sea. Superstructures for floating aids to navigation are most often damaged while being handled. The reasons for this include:

- the large size of the buoy;
- the large mass of supported components;
- the placement of the buoys; and
- the routine nature of the application.

The bell and whistle buoys have a mass of 4400 kg and 6000 kg, respectively. During recovery, the buoy must be stabilized against the vessel as the lifting hook is attached. In a typical sea state, the relative motion between the tending vessel and the buoy results in heavy contact to the superstructure. Also, there should be no points on the superstructure which can catch on the deck of the ship. An example of this would be a large diameter circular guard ring, which could be struck from below as the buoy falls in a wave trough. The superstructure supports the sound signals, which are quite heavy (the mass of the bell is nearly 150 kg). Therefore, large forces are applied to the supporting structures during impact.

Navigation buoys are typically placed to mark hazardous areas. There is limited maneuvering area for the ship, and time limits for deployment and retrieval operations. If a buoy has moved from its original location, the ship may be in shallow water, and the buoy must be pulled quickly. The time when the buoy is in the air is an extremely dangerous period. A buoy swinging on a crane is effectively out of control. It must be lowered to the deck within seconds of being pulled clear of the water, for the safety of the crew. At this time the superstructure is very vulnerable.

The routine nature of the application is another aspect which makes navigation buoys a special case. The superstructure will receive considerable knocks. This is not due to improper care but due to the frequency and commonplace nature of the operations. This work is often done in severe weather. Also, the buoys are often pulled during winter months, and stored outdoors in storage yards. There they are often moved around, laid down in the grass or on a rock, etc., for a design life of 20 to 30 years.

One important aspect of buoy handling is the manner in which the superstructures are handled around the buoy maintenance yard. Once a buoy leaves the water, it is stowed and moved horizontally. Also, even when the superstructure is disconnected from the buoy, service and

maintenance are often done with the superstructure laid on the ground. Installation of the superstructures is carried out by offering up the superstructure, horizontally, to the attachment points on the buoy.

For the open cage type of superstructure, this does not present any particular difficulties. The framework can be grappled at most points and the superstructure can be hoisted by a crane in any desired orientation. For an enclosed superstructure, additional lifting points should be provided to ease handling of the buoy in a horizontal orientation. These lift points should be at the centre of balance of the superstructure, with the signals installed. Gaskets should be attached to a mating surface with adhesive. If this is not done, it is difficult to maintain the positioning of the gasket as the superstructure is installed. During removal, the weight is taken by a crane as the attachment bolts are removed. if the superstructure is not balanced, the bolts can jam, and removal is difficult. Also, the superstructure could shift as the last bolts are removed, increasing the potential for injury.

In some cases, battery replacement and sound signal maintenance is done on board ship. Typically, the buoys have four pickup lugs arranged on a 90 degree spacing around the circumference of the buoy. Any one of these may be used for recovery, so the buoy may end up in one of four positions on the deck. For enclosed superstructures, access to the interior of the structure for signal maintenance may only be available from one side. Preferably, service could take place without having to rotate the buoy on deck.

During recovery it is important that the buoy can be approached and hooked from any direction. A pickup stick is used to stabilize the buoy against the side of the buoy tender. The hook used on the pickup stick at the Dartmouth base has a throat dimension of 12 cm, and a depth of 23 cm. The superstructure must be provided with a suitable point(s) for the pickup stick hook. **These points must be capable of withstanding a minimum dynamic load of 2500 kg.**

2.2.2 Reliability and Maintenance

According to Captain Don Wells of the Naval Civil Engineering Laboratory:

> Perhaps the most important factor in the improved use of materials in ocean and coastal engineering applications during the past 25 years is an increased awareness of the need for integrating material selection and corrosion control into the overall design process.[4]

Resistance to corrosion is achieved through use of chemically inert materials, avoidance of dissimiliar metals which might cause galvanic corrosion (e.g. aluminum and steel) and use of proper insulating methods and materials. Existing buoy hulls are painted steel, with aluminum radar reflectors and bronze signal structures and light housings.

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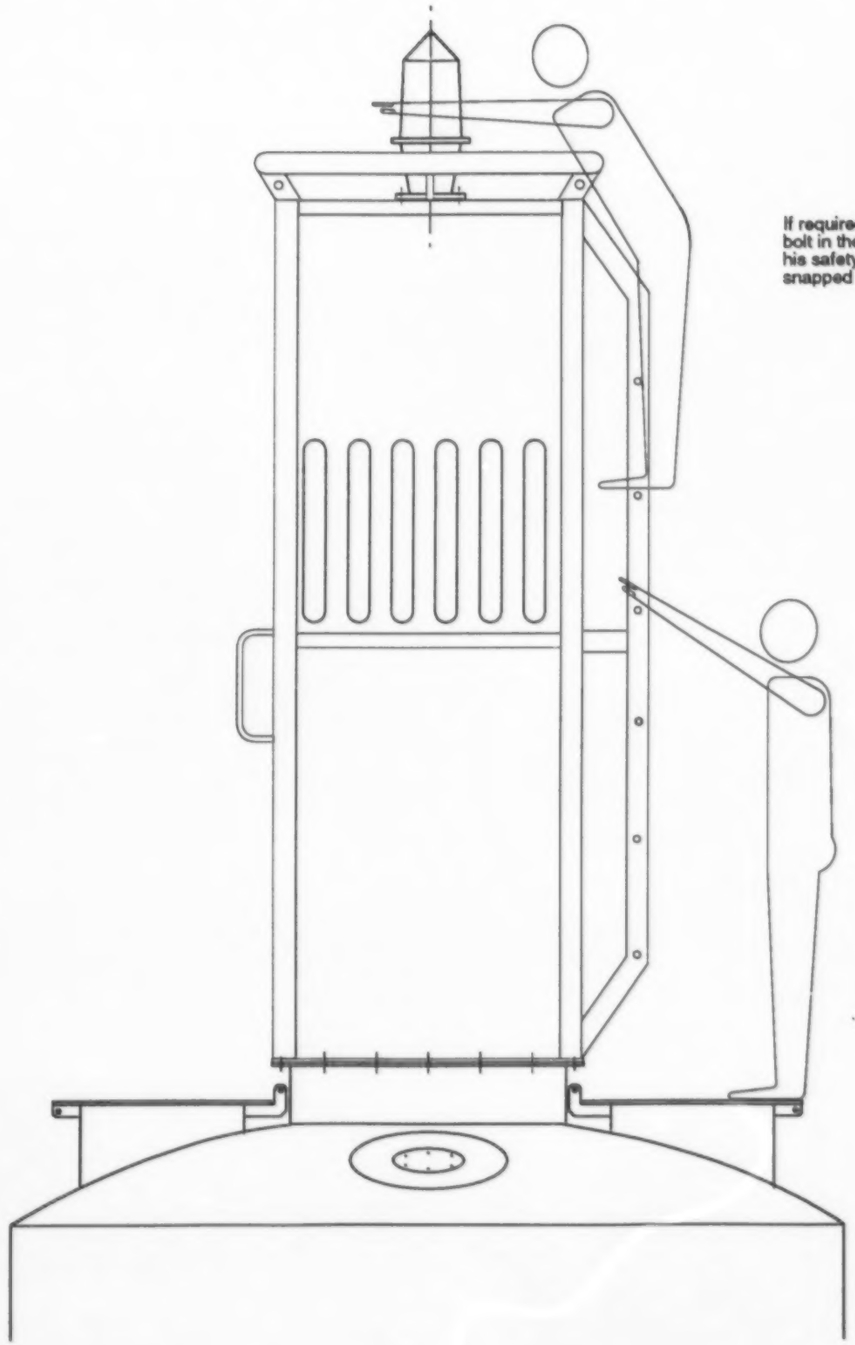
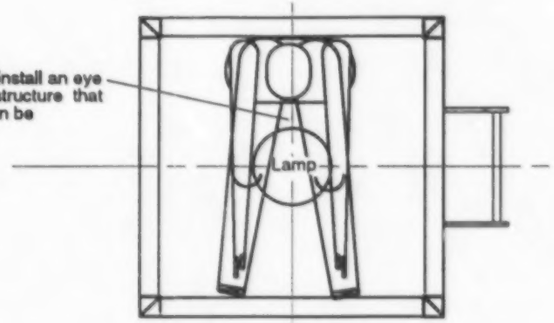
[4]Wells, Don Capt., Ocean and Coastal Engineering Accomplishments, 1963 - 1988, Marine Society Journal, Volume 22, Number 1, Marine Technology Society, Washington, DC, October 1988.

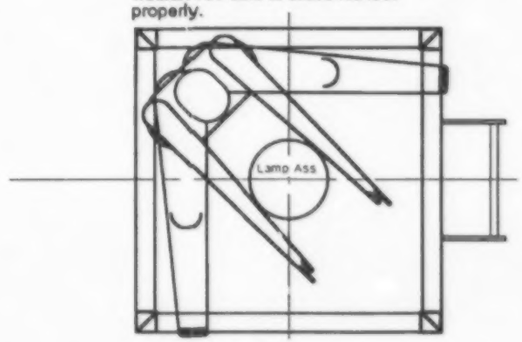


If the ring is about the same size as the structure, Bart can sit inside of it and brace his back against one side and his feet against the other. He can also support himself by gripping the lamp with his legs. This may not work as well if perhaps Bad Bart's buddy has shorter legs.

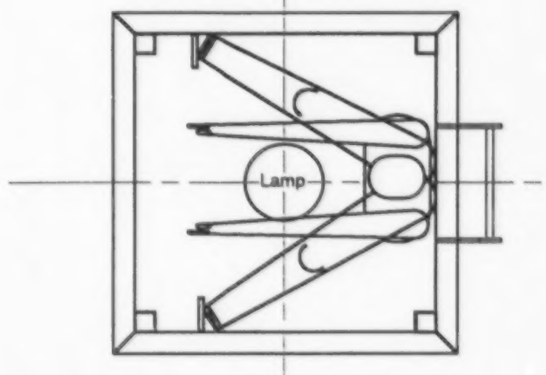
If required, we could install an eye bolt in the top of the structure that his safety harness can be snapped into.



If the guard ring was the same size as the super "S", Bart could sit with his back in one corner and his feet braced against the opposite sides (knees bent). The ring would need to be high enough to provide proper support yet not too high, for he wouldn't be able to brace his feet properly.

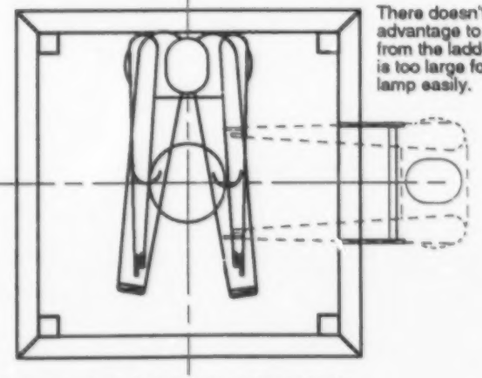


In a slightly larger guard ring (48" A/F) Bart could sit inside on the top of the super "S" if some type of foot brace was attached to either the top surface of the structure or the side of the pickup ring.



Other than the one variation shown above, there doesn't seem to be any half decent method for Bart to brace himself securely while sitting inside the larger size guard ring

There doesn't seem to be any advantage to having Bart work from the ladder, the structure is too large for him to reach the lamp easily.

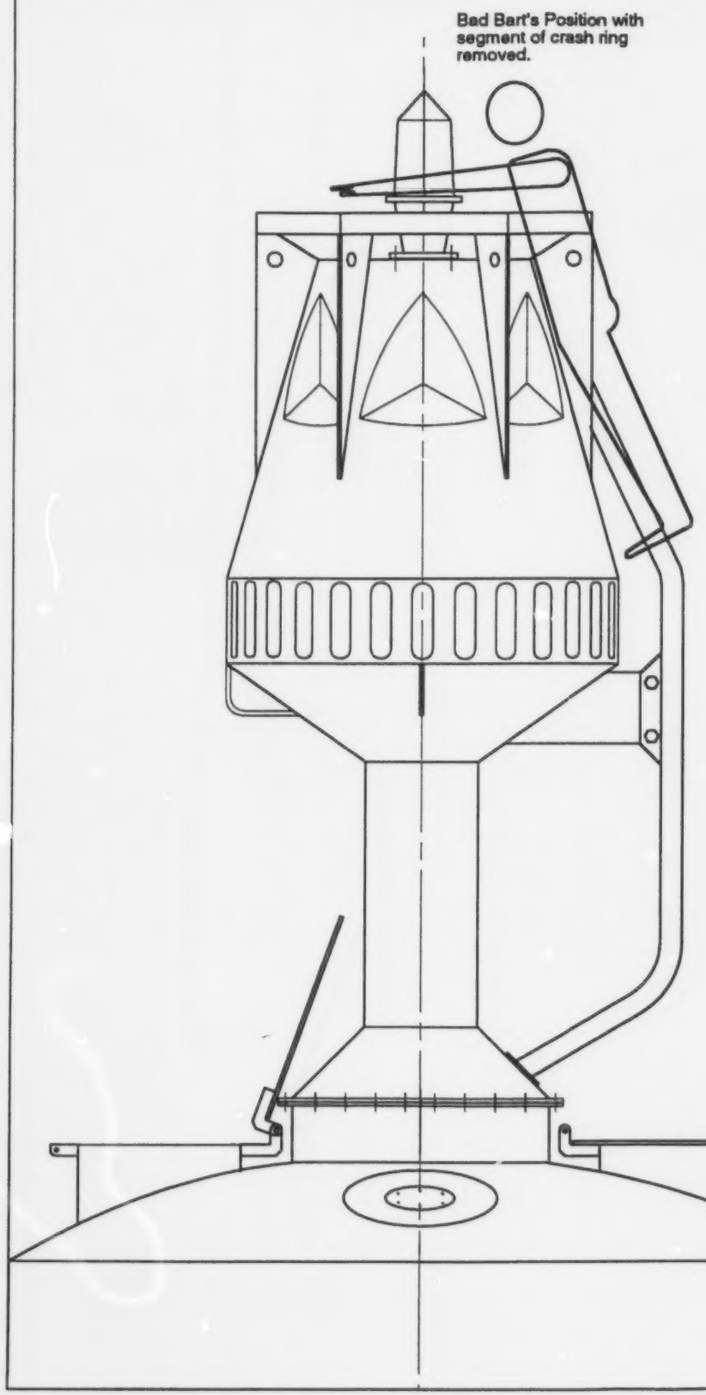


If we were to weld/bolt rings or hoops to the top surface as foot braces, somebody is sure to attempt to pick up the whole buoy by them sooner or later.

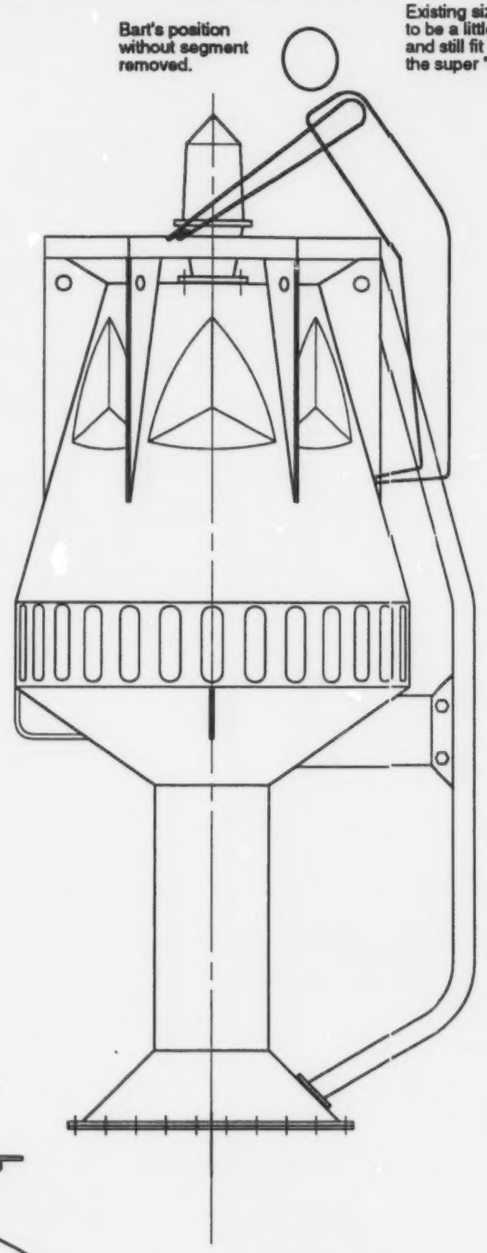
	P HUNTLEY	TAVEL
		Concept #1—Space Frame Construction

Figure 4 Whistle Buoy Light Signal Maintenance Ergonomics

TAVEL



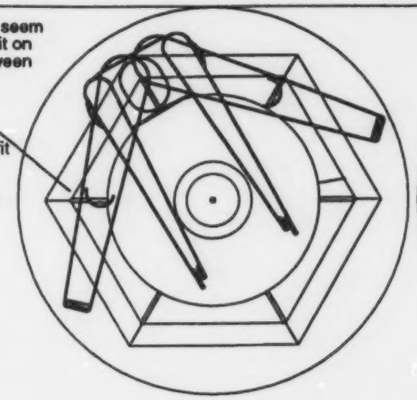
Bad Bart's Position with segment of crash ring removed.

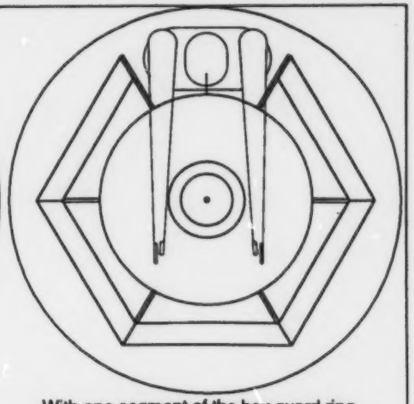


Bart's position without segment removed.

Existing size of guard ring; this would seem to be a little too small for the man to sit on and still fit his legs down through between the super "S" and the gussets.

There isn't enough room for Bart's leg to fit down by the gusset(this would depend on the size of the man).

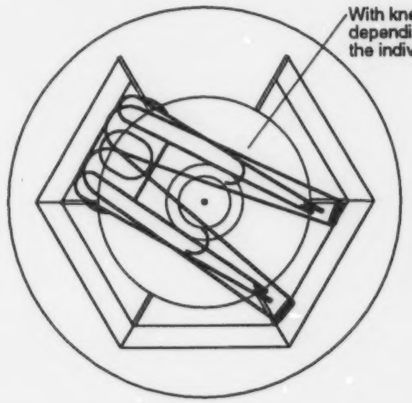


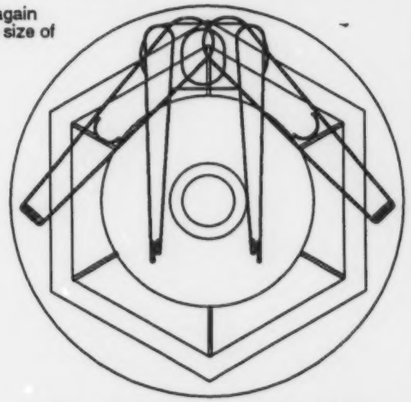


With the existing size of guard ring, Bart can sit on the top surface of the super "S" while bracing his back against the ring on one side and his feet on the other. He can also help to retain himself by holding onto the lamp base with his legs.

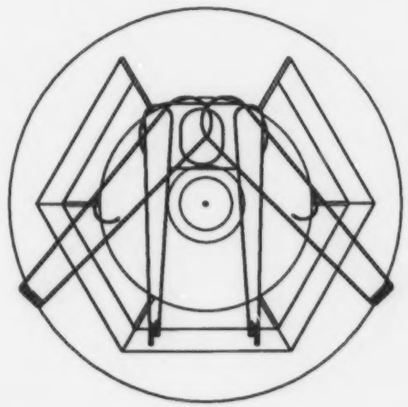
With one segment of the hex guard ring removed, the man can get apx 5.5" closer to the lamp. This also creates a channel within the gussets that will help give lateral support for the man while he is standing at the top of the ladder. Also he doesn't have to climb out over the outer edge of the ring to reach the top surface of the structure.

With knees bent again depending on the size of the individual





With a 38" ID guard ring, Bart's leg's will fit down through by the gussets and he has a half decent place to sit on the ring. Also, a waist mounted safety harness can be clipped into the gusset between his legs.



With either size of guard ring, Bart can sit on the top of the enclosed structure with his legs sticking out under the ring thus using the lamp & the guard ring to steady himself.

	P HUNTLEY	TAVEL
		Stressed Skin Ergonomics

Figure 5 Bell Buoy Light Signal Maintenance Ergonomics

Materials required for regular maintenance and emergency repairs should be readily available. Preferably, maintenance techniques are consistent with the techniques and skills required for existing buoy hull maintenance program. The need to call upon demanding skills or exotic materials presents maintenance problem over the long term. The materials and coatings selected must exhibit good colour retention in the presence of salt fog and sea spray, UV light, and temperature extremes.

One of the major sources of damage to navigation buoys is vandalism, typically from small arm gunfire. While this problem is less for the larger coastal sound signal buoys, the potential for vandalism must be considered as well.

Safe and comfortable signal maintenance at sea can be broken down into three activities:

- boarding;
- climbing the superstructure; and
- servicing the light.

Typically, small craft are used for boarding. The safest and preferred approach is from the leeward side. Depending on the current, wind, and mooring forces at play, the buoy may be positioned in any circular orientation, and may be rotating as well. Therefore it is important that footfalls and grab points be available from any point on the circumference of the buoy, and not just in one location.

There must be a means of climbing the superstructure. On the open frame superstructure, bracing is used to climb to the top of the structure. On an enclosed superstructure, some type of ladder is required. This ladder can be either built into the superstructure, or provided externally. Integral ladders tend to form pockets which can be difficult to clear of ice, and interference with internal components can be a problem. External ladders are easier to climb and de-ice, but are prone to damage from collisions with the tendering vessel. **A minimum of 200 mm of toe room must be provided for safe climbing.**

During the development of the prototype enclosed superstructures, considerable attention was paid to proper ergonomic design of the ladders and working position for light signal maintenance. Figures 4 and 5 show the working positions for the whistle and bell buoys, using a 95th percentile human figure, called here "Bad Bart".

2.2.3 Icing

For a 2.9 m navigation buoy in coastal waters, the majority of icing will be confined to a zone from the buoy deck to a height of about 1.2 to 1.5 m above the deck. Although icing above 1.5 m above the deck will occur in severe conditions, the height to which spray is thrown by passing waves is generally limited by wind and sea conditions to about two metres. In lighter sea conditions, heavy icing will occur in the zone at or near the waterline, but this tends to break way from the vertical hull surfaces as the thickness increases.

Icing starts and builds up on or around deck projections such as coamings, mooring points, and brackets. The clear areas of the deck itself tend to stay relatively clear of ice, due to their being swept clear by passing waves and heavy spray. To reduce the chances of large amounts of ice buildup near the buoy deck, the number of protruding structures, such as brackets, well covers and latches, and support structure members has to be minimized. For structures in the icing zone, the use of 'clean' designs having a minimum of surfaces, joints, and parts which can provide structural attachment points for ice is recommended. Built-up ice can 'key' into these joints and surfaces, making removal by natural and manual means more difficult.

Ice removal from buoys at sea is typically accomplished by a combination of natural forces and manual intervention. Of these, the former is of course the preferred option. Unfortunately, in many instances by the time the natural forces come into full play, a partial or complete loss of buoy function has occurred. The following are some of the factors which enhance natural ice removal:

- design to allow the natural scouring and melting action of seawater waves to undermine the structural integrity of the attached ice and thus enhance the removal of ice by gravity and buoy motion;

- use of materials and designs capable of withstanding the considerable abuse involved in manual ice removal; and

- use of materials and coatings which provide a low degree of grip for the ice, so that as it softens due to increasing temperatures or washover it is more effectively removed by gravity or washover forces, or it breaks away more easily when struck.

3 CONCEPT DEVELOPMENT

After investigation of the requirements for the enclosed superstructures, the project proceeded through concept development. This comprised two tasks: Task 3—Develop Conceptual Designs, in which a variety of potential concepts were explored; and Task 4—Refine Selected Design Concepts, in which these selected concepts were advanced to a greater level of development.

The initial set of concepts arising from Task 3 was reviewed at a meeting held in Ottawa on January 18, 1991, and three concepts were selected for advancement. These three concepts, once having been further developed, were reviewed at a concept selection meeting on February 12, and two were selected for detail design and fabrication.

3.1 Initial Concept Development

During the initial concept development, a variety of materials and constructions were considered. Material selection was narrowed to the following:

Aluminum alloy
Carbon Steel
Stainless Steel
Galvanized carbon steel
Polyethylene
Glass reinforced plastic (filament wound or hand layup)

All of these materials are well known, and their properties and fabrication techniques well understood. One recent innovation in buoy technology is the application of DuPont Surlyn closed cell foam for specialized buoy applications. Surlyn is a thick walled, closed-cell thermoplastic polymer that is ionically cross-linked through the reaction of copolymer foam. It is extremely rugged and durable, and possesses excellent structural strength for its weight. It is typically used in combination with marine grade aluminum central core structures to form strong and lightweight buoy hulls in many different form factors.

Some of the properties of Surlyn which make it attractive for buoy structures are as follows:

- it contains UV stabilizers and full colour penetration for excellent colour retention;
- it can be scored or perforated at any time to accommodate masts, gussets, cables, etc.;
- nicks, cuts, chips, and bullet holes do not affect the pigmentation, structure, and buoyancy;

- radar targets inserted into custom-cut sleeves in solid Surlyn retain angularity better and longer than those exposed to the environment, hence radar visibility is extended—the Surlyn itself is essentially radar transparent; and

- Surlyn foam is not damaged by freezing and ice.

This material was particularly interesting for this application because of its excellent ice phobic properties. Ice tends simply not to form on the surface of this material. Should ice buildup occur, the resiliency of the material should cause the ice to release when struck. The foam resists damage from ice removal equipment, and damage, when it occurs, has no serious detrimental effects. The foam is fully pigmented and very durable, so no loss of function occurs.

Surlyn was not included in the above list of suitable materials because it was not viewed as a structural material, but rather as a cladding material. Additional information on Surlyn foam is given in Appendix B.

Based upon this initial review, four approaches were considered:

1. **Enclose a rectangular tubular structure with covering panels**. Material for this approach could be steel, stainless steel, aluminum alloy, or pultruded fibreglass structural tubing.

2. **Custom filament wound or hand layup FRP structure, with cutouts and internal supports as required**. Shape, wall thickness, and filament orientation could be varied to suit the loadings along the length of the structure. The need to provide for installation and support of the sound signal, sealing bulkheads, cabling conduit, and mounting points complicate this approach. A risk is that the external integrity of this structure will be damaged during a number of years at sea following damage resulting from ice removal. Little or no literature exists in this area and it is well worth investigating to ascertain the risk related to this approach, which offers corrosion advantages when compared to other materials.

3. **Cylindrical hard shell pipe structure.** In this approach, the basic strength comes from an outer shell of aluminum or steel. Internal brackets are provided to mount sound signals, etc. A modification of this approach would be to continue the structure from the sound signal on up with an open frame for sound signal performance and signal light maintenance.

4. **Cylindrical soft shell pipe structure**. In this approach, the strength is derived from an inner pipe and frame structure of steel, fibreglass, or aluminum. To this an outer covering of Surlyn foam or polyethylene pipe would be applied.

Using these four basic approaches, thirteen concepts were developed for discussion. In most cases more than one material could be selected as a possible material for any concept. These concepts are shown in Figure 6.

From these thirteen concepts, three were selected for further development. The three concepts selected represented different fundamental types of construction. These were:

- Concept #1—Space Frame Construction
  The construction of this concept would be made up of a framework of structural metal sections, enclosed by appropriate panels and bulkheads;

- Concept #2—Stressed Skin Construction
  In this concept, the strength is derived from the external skin of the structure. The skin is reinforced as required at major load points and internal structures for mounting of the sound signals, etc.; and

- Concept #3—Tubular Mast
  The strength in this concept is provided by a pipe or mast. This mast would support a cage-like structure to enclose the sound signal. Part or all of the superstructure would be covered in Surlyn foam to provide daymark colour, minimize ice accretion, and provide protection for internal components.

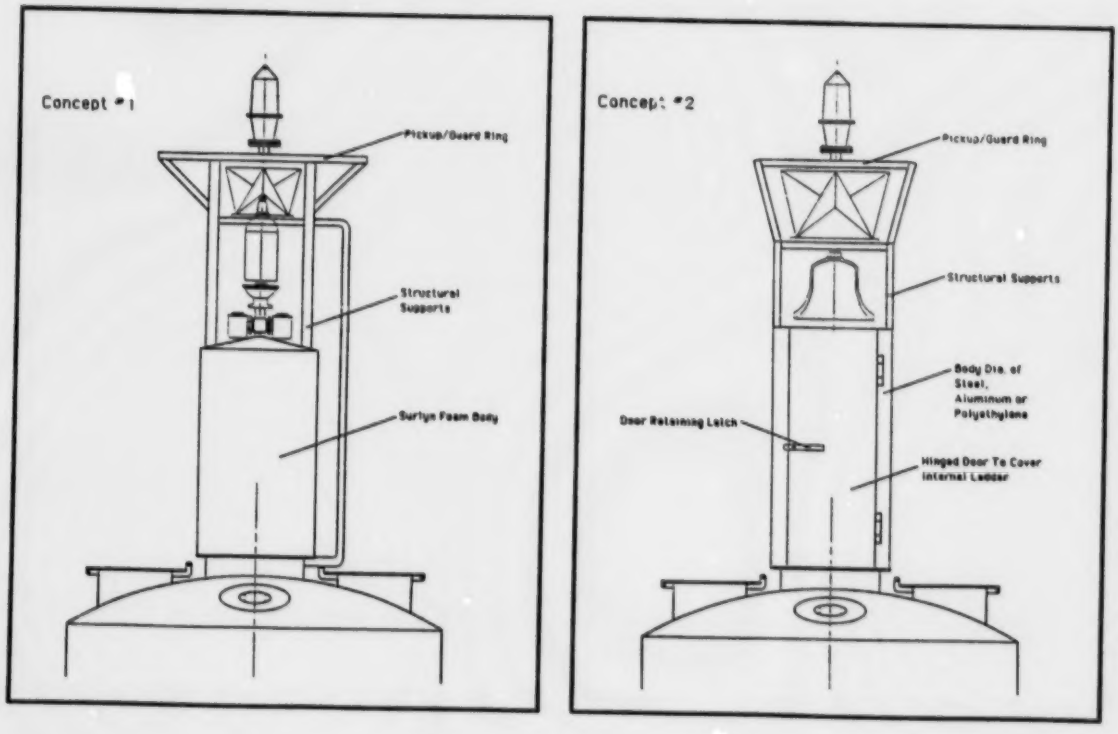
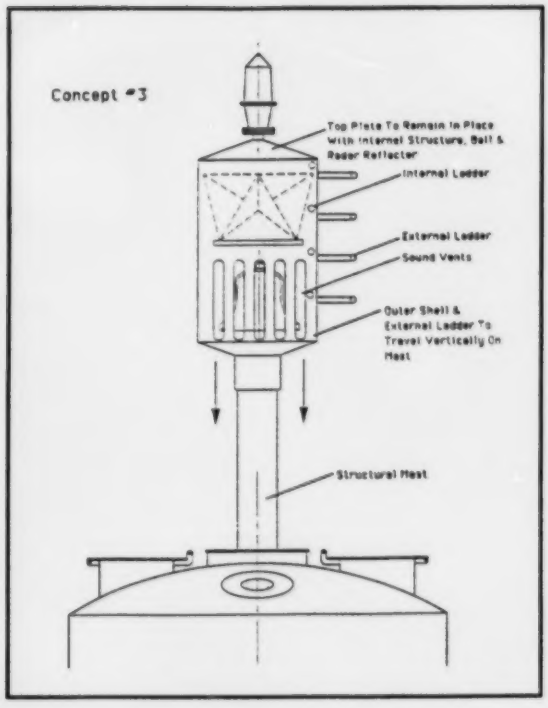
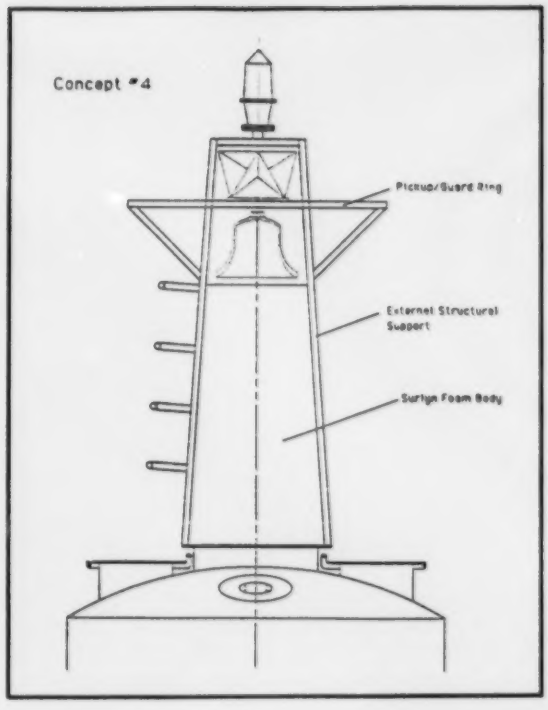
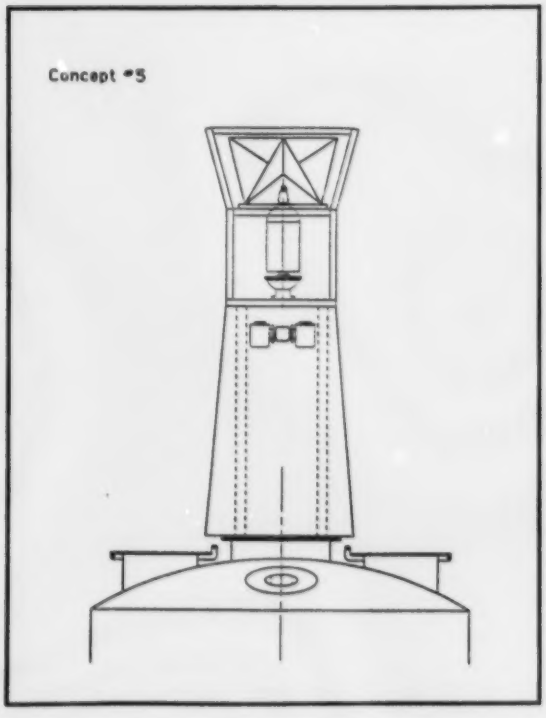


Figure 6 Preliminary Concepts


Concept #3
Top Plate To Remain In Place With Internal Structure, Bell & Radar Reflector
Internal Ladder
External Ladder
Sound Vents
Outer Shell & External Ladder To Travel Vertically On Mast
Structural Mast





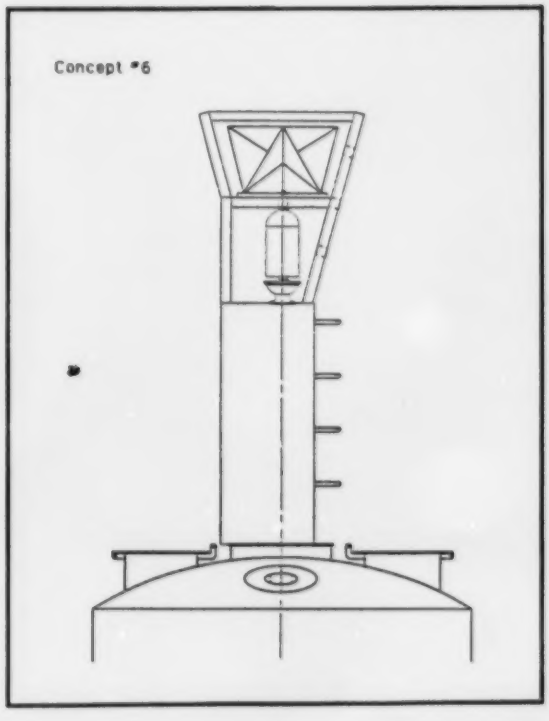


Figure 6 (cont.) **Preliminary Concepts**

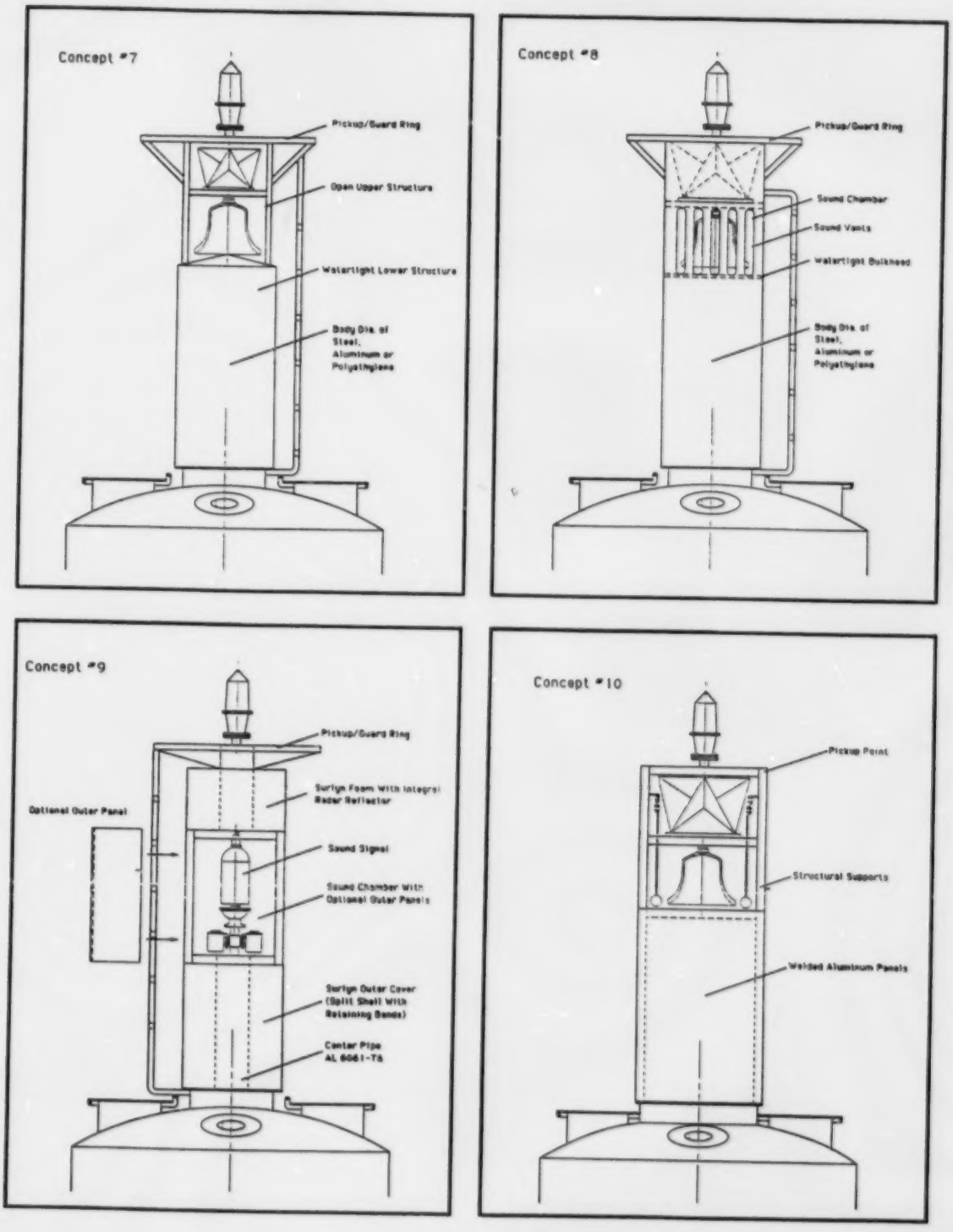
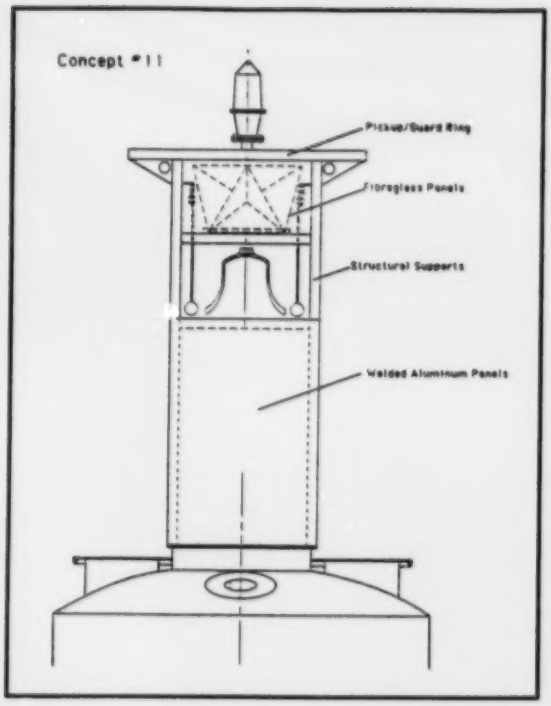
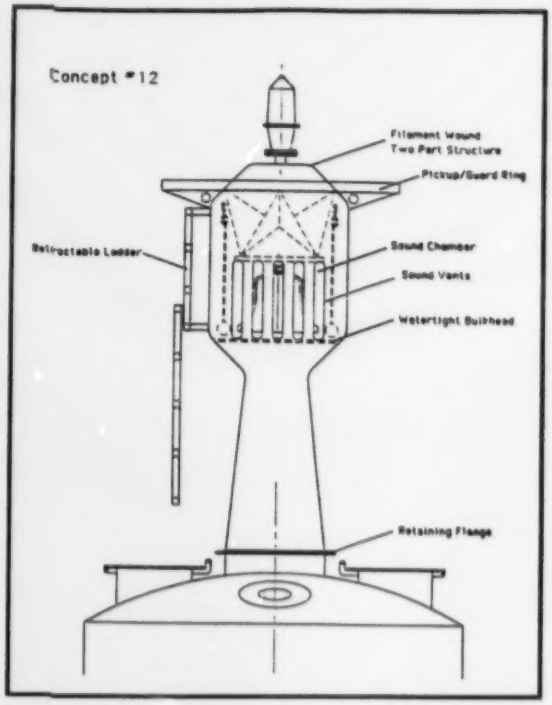


Figure 6 (cont.) **Preliminary Concepts**





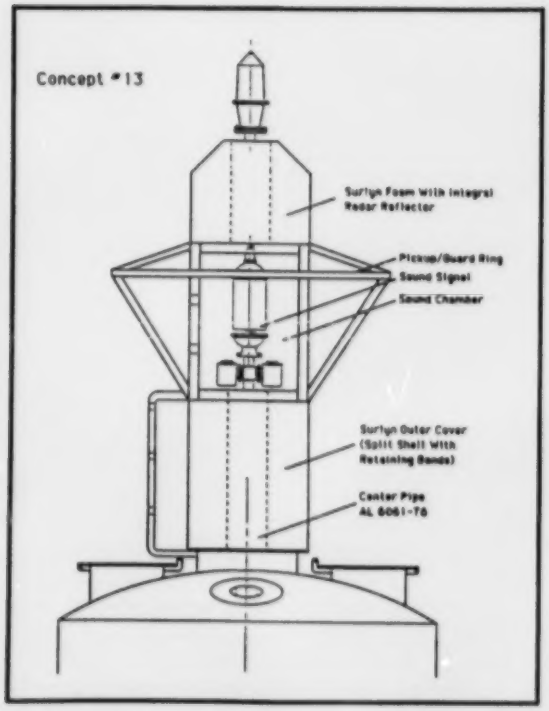


Figure 6 (cont.) **Preliminary Concepts**

3.2 Concept Advancement

At the time of the concept review meeting, the material selection for structural components had been limited to steel, aluminum, stainless steel, and glass-fibre–reinforced plastic(GRP). Options were left open to use any of these materials, or a combination of materials, for any of the concepts. Materials were selected for each concept for advancement, and a discussion of the refined concepts follows. Concept Summary sheets for the three advanced concepts are included here as Figures 7 to 9.

Concept #1—Space Frame Construction

This structure is a square cross-section structure, built up of square section tubular aluminum and enclosed with aluminum sheet panels. The enclosing panels are recessed to allow the incorporation of optional flat Surlyn sheets. For the top section, the enclosing panels would be a radar transparent material, such as polyethylene. If Surlyn is used for the bottom section, these panels could be Surlyn as well.

Concept #2—Stressed Skin Construction

This modular concept consists of three major components:

- the pedestal module;
- the signal module; and
- the top cover and guard ring module.

During assembly the signals would be mounted to a sub-frame. This sub-frame would then be assembled to the pedestal module, and a top cover placed over all.

Concept #3—Tubular Mast

The signals are supported on a tubular mast structure which is enclosed in Surlyn foam. The foam cover provides the colour, increases daymark area for improved visibility, and improves ice accretion and removal performance. Stainless steel was selected for the mast. GRP was rejected due to concern over the long-term strength of the base connection.

A stainless steel cage is used to carry the loadings up through the sound signal section. This provides maximum crash protection and corrosion resistance. The signals are mounted on a modular sub-frame, and protected by a Surlyn foam outer housing.

In summary, the three concepts exhibited varying attributes and trade-offs.

- Concept #1 would be a medium-cost structure, but would require less maintenance than Concept #2 and should demonstrate superior icing performance.

- Concept #2 is a basic superstructure having the advantages of lower initial cost and ease of repair. Performance would be significantly improved over the present superstructures.

- Concept #3 is a deluxe model. It would be virtually maintenance-free, but would be considerably more expensive than Concept #2, and somewhat more expensive than Concept #1.

ENCLOSED SUPERSTRUCTURE CONCEPT SUMMARY

Concept Name Concept #1
Space Frame

Material Aluminium
6061-T6

Daymark Area
3.2 m^2

Weight
165 kg

Centre of Gravity
1370 mm

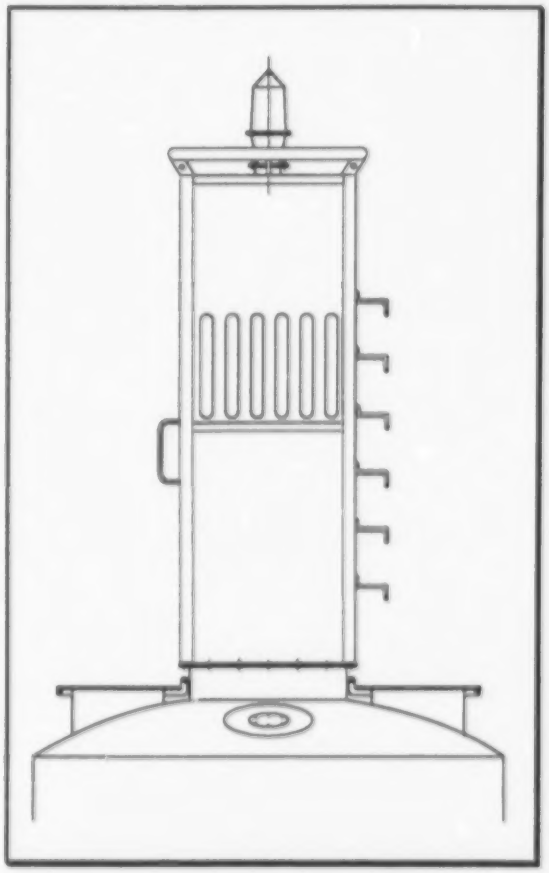
Production Cost (est.)
$5000

Repairability

Easy [Medium] Difficult

Durability

Low [Medium] High



DISCUSSION

This structure is a square cross-section structure, built up of square section tubular aluminum and enclosed with aluminum sheet panels. The alloy would likely be Al 6061-T6. Although it is not specifically a marine grade alloy, its improved strength and weldability make it a better choice for superstructures. Marine grade (i.e. 5000 series) alloys would be selected for immersion applications.

The enclosing panels would be recessed to allow the incorporation of flat Surlyn sheets. This is an option and would only be done when it is clearly demonstrated that Surlyn has significant performance advantages in icing conditions. For the top section, the enclosing panels would be a radar transparent material, such as polyethylene. If Surlyn is used for the bottom section, these panels could be Surlyn as well.

This concept requires aluminum welding capability for fabrication and repair, typically available in most medium to large industrial centres.

Figure 7 Concept #1 Summary Sheet

ENCLOSED SUPERSTRUCTURE CONCEPT SUMMARY

Concept Name Concept #2
Stressed Skin

Material
Steel

Daymark Area
2.9 m^2

Weight
315 kg

Centre of Gravity
1560 mm

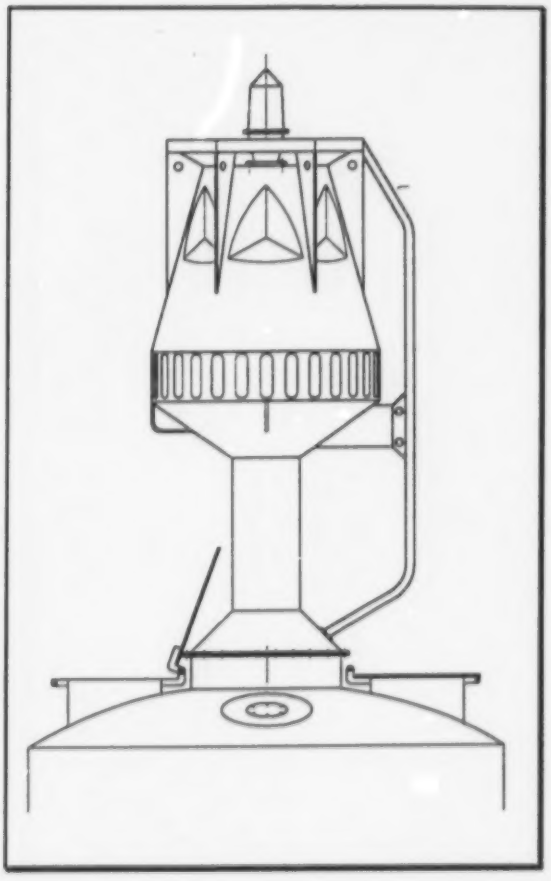
Production Cost (est.)
$2500

Repairability

[Easy] Medium Difficult

Durability

[Low] Medium High



DISCUSSION

This modular concept consists of three major components:

- the pedestal module;
- the signal module; and
- the top cover and guard ring module.

During assembly the signals are mounted to a sub-frame. This sub-frame is assembled to the pedestal module, and then a top cover is placed over all.

This is a painted steel structure, which would be easily repaired and maintained using conventional steel maintenance methods and equipment. Fabrication would be somewhat specialized, as it would require access to a shop with large rollers to roll the top cone. Alternatively this could be made of octagonal construction.

Figure 8 Concept #2 Summary Sheet

ENCLOSED SUPERSTRUCTURE CONCEPT SUMMARY

Concept Name Concept #3
Tubular Mast

Material Stainless Steel
SS 316

Daymark Area
2.4 m^2

Weight
240 kg

Centre of Gravity
1690 mm

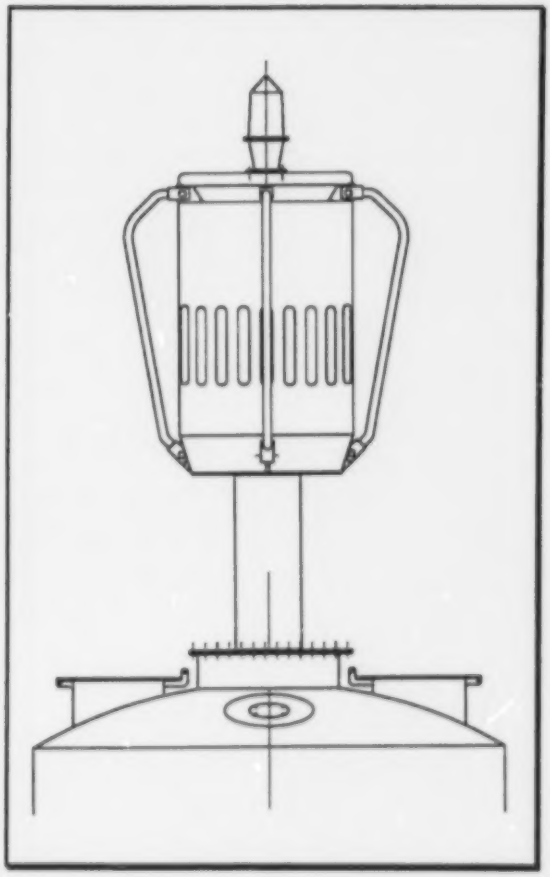
Production Cost (est.)
$7500

Repairability

Easy Medium [Difficult]

Durability

Low Medium [High]



DISCUSSION

The signals are supported on a tubular mast structure which is enclosed in Surlyn foam. The foam cover provides the colour, increased area for improved visibility, and improved ice accretion and removal performance. All materials were considered for the mast. GRP was rejected due to concern over the long term strength of the base connection. Aluminum was selected initially, but stainless steel is being re-considered, and this has not been finally resolved.

A stainless steel cage is used to carry the loadings up through the sound signal section. This provides maximum crash protection and corrosion resistance. The signals are mounted on a modular sub-frame, and protected by a Surlyn foam outer housing.

This model would require specialized fabrication and repair facilities, for the Surlyn foam and stainless steel welding. It would be designed to require no routine maintenance. Colour change would be done by replacing the Surlyn foam jacketing.

Figure 9 Concept #3 Summary Sheet

4 DESIGN AND FABRICATION

4.1 Material Selection

At the design selection meeting, steel was chosen as the material for both the selected designs. Some discussion of the rationale for this choice is given in the following paragraphs. Note that each material has its good and bad points. The following discussion is not a complete review of each material, but rather a summary of the known specific disadvantages and advantages of the respective materials which led to the selection.

Only two readily available stainless steel alloys are suitable for marine use, Type 304 and Type 316. Type 316 is best for salt water, particularly where the metal is submerged. Stainless steels are difficult to form and shape, they transmit heat poorly, and are prone to severe warping during welding. They do not cut readily with a cutting torch, therefore may present repair problem for yards not equipped with plasma arc cutting equipment. The stainless steels are not easy to machine or cut cold, and they pose special corrosion problem in welded segments due to carbide precipitation in the heat affected zone. In addition, stainless steels are expensive ($ 5.93/kg) compare to steel ($ 1.16/kg).

Aluminum alloys specifically suited for marine use are quite expensive ($ 6.53/kg), the cost of fabrication being in general as much or more than for steel. CCG experience with aluminum has not been positive. In their experience aluminum cannot be welded for repair after about five years of exposure to the marine environment.

Fibreglass, properly laid up with a minimum of resin in proportion to glass fibre, can be a very tough material. In assessing the strength of fibreglass, the method of construction is an important factor. The presence or lack of bubbles, voids, and dry areas, and the orientation and number of layers of fibre all have an appreciable effect. The advantages of fibreglass construction are generally realized in composite shell structures, particularly those having compound curves. The long-term life of plastic marine structures has to be proven; all resins break down with age and sunlight, by fatigue and micro-crazing. There are examples of fibreglass boats in excellent condition after twenty years. Typically these have been meticulously maintained, particularly in making sure that damage to the gel coat or outer protective layer is promptly repaired.

The greatest advantage of steel is the combination of strength and ductility this material possesses. Steel will elongate 30 to 40 percent before failure and may sustain repeated blows or loads that would shatter aluminum or fibreglass and still be serviceable. Except for corrosion, when it is permitted to progress, steel does not deteriorate with age; its properties remain constant. Corrosive decay is avoidable in most cases, because it gives plenty of warning and correction is easy. Assuming proper design to allow access to every part of the superstructure, it is not unreasonable to expect that it should last twenty to thirty years. Steel, per pound or by strength-pound ratio, is the least costly of the suitable materials. **Steel, on balance, is likely to be the least expensive, most durable material available for**

this application. This is particularly true as the superstructures are intended to be retrofitted to the existing steel buoy hulls. The implications of this are twofold:

- any advantages resulting from reduced maintenance for alternative materials could not be fully realized since the steel buoys would have to be serviced at shorter intervals; and

- the large mass of the steel buoy hulls presents particular problem for superstructures of fibreglass or aluminum, which would be vulnerable to impact damage resulting from contact forces generated by the large attached mass.

The greatest potential for advanced composite materials to buoy construction will be on the next generation of buoy development, where a superstructure, hull, mooring and anchor system can be engineered as one system, taking full advantage of the properties of recently developed materials and fabrication techniques. As Captain Hann of the CCGV Edward Cornwallis stated **— any implementation of an extended maintenance cycle should give thorough consideration of the buoy "from light to anchor".**

Composite materials have advanced beyond conventional fibreglass construction. New fibres and resins are appearing, with extraordinary properties. For example Spectra™ fibre from Allied Signal is increasingly being used for marine applications. Spectra has very high impact strength. It is displacing Kevlar as a material for body armour such as bullet-proof vests. The use of steel versus composite materials was discussed with Dr. J. Gordon Murphy of General Composite Technology (GCT). GCT is a member of the ***marine composites alliance***. Dr. Murphy summarized his thoughts in a letter, which is included as Appendix C.

4.2 Whistle Buoy Superstructure Design

The whistle buoy superstructure design, shown in Figures 10 and 11, is a straight-sided structure of square cross section. The primary strength members are the vertical uprights at the four corners, which are 75 mm x 75 mm x 3 mm tubular square section with boxed in ends. There are a number of horizontal bulkheads to provide sealing and structural support for the sound signal and associated plumbing. These bulkheads are constructed with 50 mm x 50 mm x 3 mm square tubing with plating of various thicknesses as required.

Torsional rigidity is provided by a combination of tubing cross section and welded-in plating on the bottom section of the superstructure. This plating is 3 mm thick, and in combination with the lowermost bulkhead, form a large volume watertight chamber at the base of the superstructure. This area has been designed to provide potential storage for rechargeable batteries for future solar powered buoys. The panels of this watertight chamber (which is in the zone of maximum icing) are covered in Surlyn foam. The whole of the superstructure exterior presents a very clean appearance, which should minimize ice buildup, particularly with the Surlyn panelling. One side panel for the bottom compartment is removable for access.

The next section of the superstructure is a plenum chamber for the air valve assembly. This section is boxed in on two sides with welded-in steel panels. The other two sides are enclosed with removable stainless steel panels, which are bolted in place. The panels are removed to service the air valve assembly during assembly and maintenance. There are openings across the bottom of the width of the removable panels, to allow for low pressure head entry of the large volume of air required during the intake cycle of the whistle action. The whistle is activated by air drawn into the large central tube through the air valves as the wave trough moves past the buoy, and expelled through the whistle as the wave crest passes. The panels in this section are also covered in Surlyn bonded to the steel panels.

The next section is the whistle compartment. The enclosing panels in this section are Surlyn only. All of the Surlyn panels are a special composite construction consisting of three densities of Surlyn, including an unfoamed outside layer, with a layer of rip-stop nylon reinforcing mesh. Narrow slots (25 mm) have been cut in the panels to minimize the sound reduction.

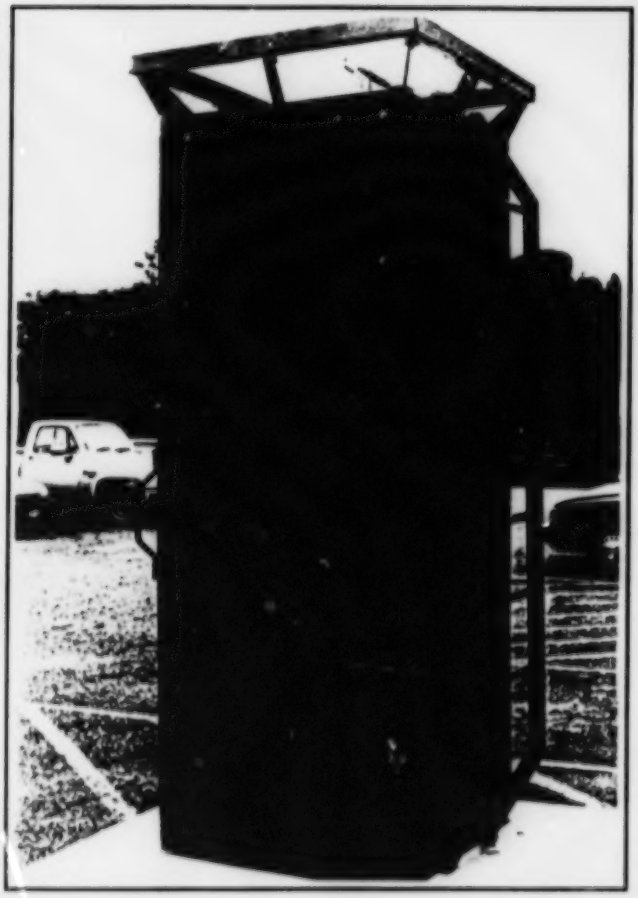


Figure 10 Prototype Whistle Buoy Superstructure

Sound testing was carried out to determine the acoustic insertion loss of the panels. Four configurations were tested—empty (no panels), solid panels, and panels with two widths of slots, 25 and 50 mm. Figure 12 shows the results of this testing. As might be expected, the greatest sound transmission occurred with no panels, and the worst occurred with the solid panels. Acoustic insertion loss with the solid panels was 8 - 10 dB(A) re .0002 uB. There is considerable sound deadening within the foam. Despite the reduction in energy, the drop in perceived loudness was surprisingly low. Of the slotted configurations tested, the best performance was realized with the narrower slots. Acoustic insertion loss with the 25 mm slotted panels is 1 - 1.2 dB(A) re .0002 uB, which is well within the established requirement of 3 dB.

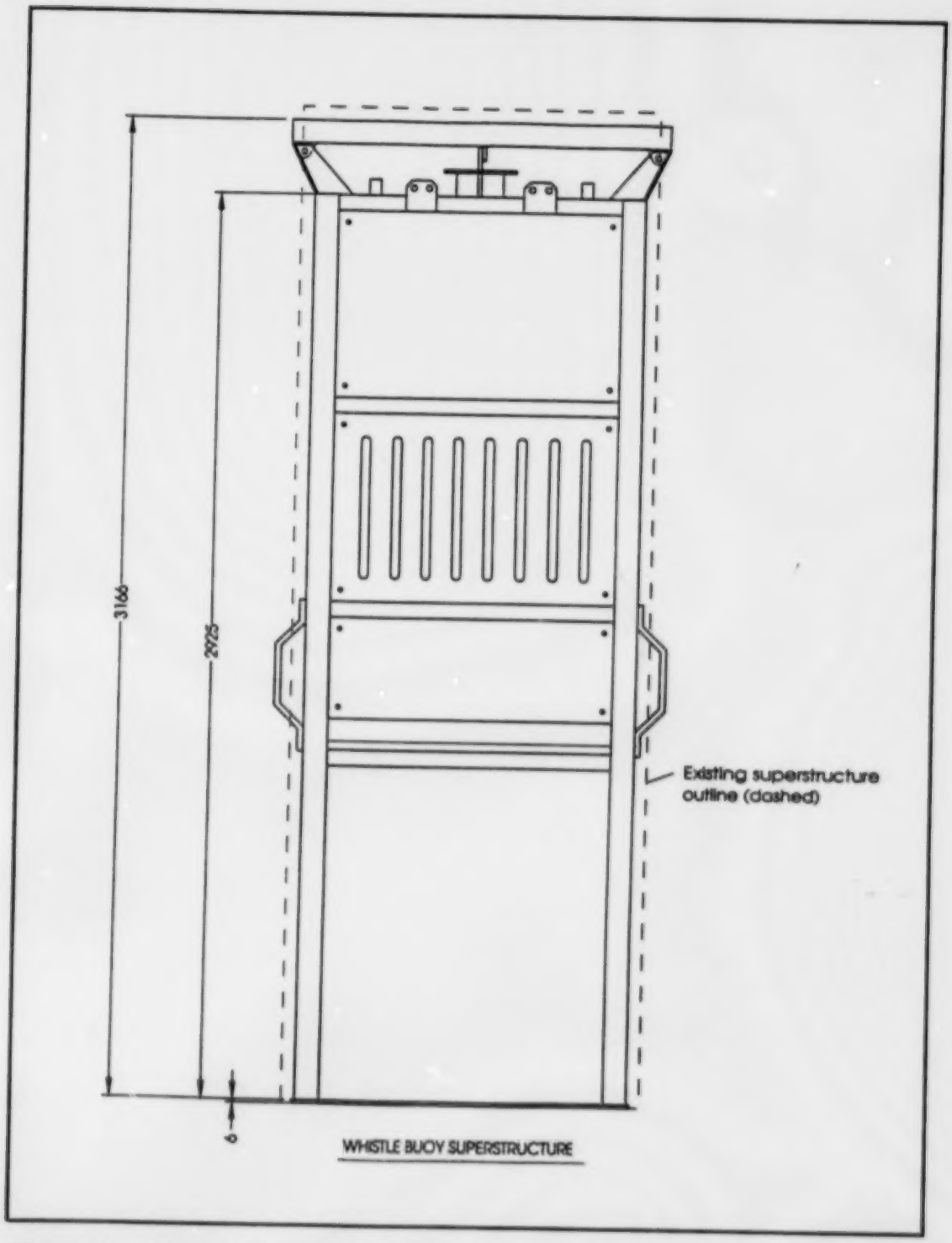


Figure 11 Whistle Buoy Enclosed Superstructure Drawing

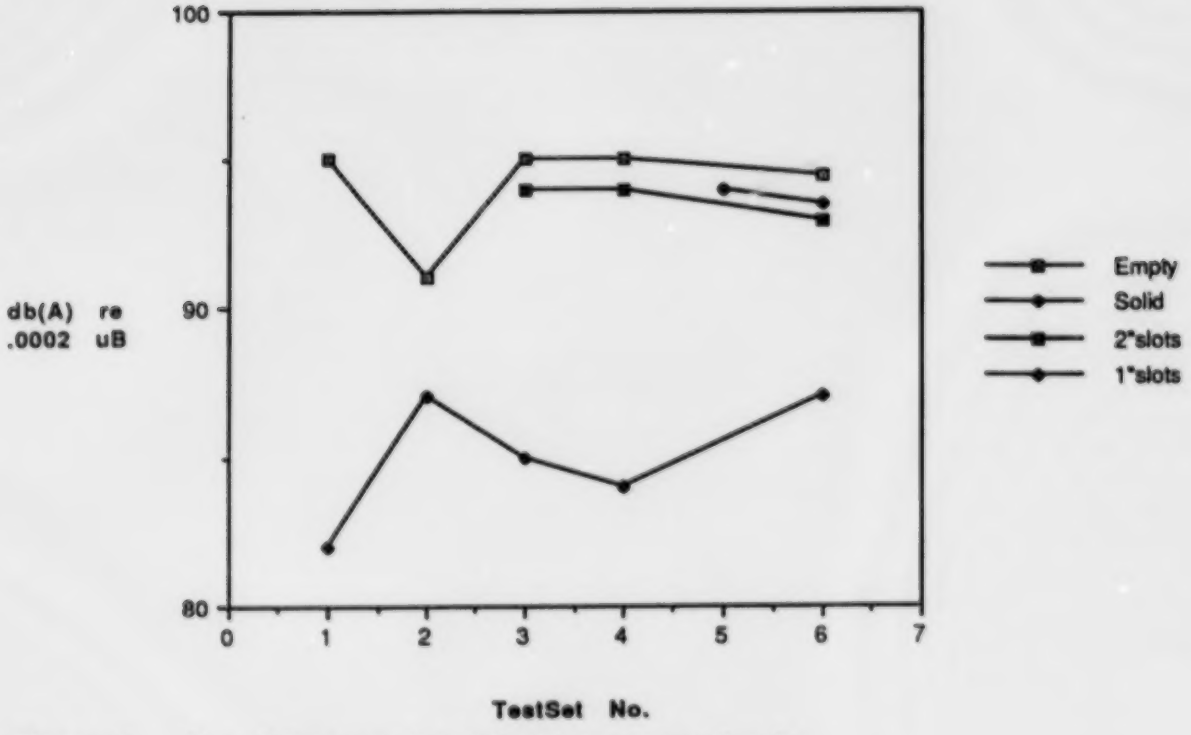


Figure 12 Sound Pressure Level for Various Test Panels

There is no steel backing on the sound enclosure panels, in the interest of minimizing top weight. Instead, a compliant approach has been adopted. The Surlyn panels are backed by stainless steel aircraft cable diagonals, which absorb wave impact loadings as the panels deform under the bending loads. The panels themselves are of a construction developed for daymarks, and have been tested with good success by the US Coast Guard. The panels are well outside the normal wave action, but may be damaged or lost due to breaking waves or buoy rollover.

If one or more of these panels is lost, there would be no impairment of buoy function. In fact, sound signal level would be improved, and the superstructure would perform similiarly to the existing open frame design. Both superstructures have been designed with removable, optional panels over the sound signal compartments. Steel panels are being used on the bell buoy.

The topmost section encloses the standard CCG aluminum octahedral radar reflector, again covered with Surlyn panels. The configuration of these panels is similiar to those of the sound signal compartment, but without the slots.

The top deck of the superstructure is diagonally cross-braced with 50 mm square tubing, and plated in to provide a smooth flat deck area for light signal maintenance. The top deck is surrounded with a very strong crash frame, constructed of 75 mm x 75 mm x 3 mm square

tube. This frame is attached at eight points around its perimeter, to gussets welded to the frame of the top deck. Bolted connections secure the crash frame to the superstructure, so that it may be easily removed and replaced if damaged.

Mounting points for cardinal topmarks, RACONs, and solar cell arrays were considered. There is ample mounting surface and structural framework available. Following discussion with CCG personnel, we decided not to actually fit mounting lugs or provide mounting holes on these prototypes. They were not to be fitted with any of the above devices. Nevertheless, they could be easily retrofitted in the future.

An access ladder is required, although it presents a problem area for icing. A very conservative approach to ladder design was adopted, after considering some innovative alternatives developed during the early phases of the project. This was done for safety and security of service personnel. The key features of the ladder are:

- it is constructed of readily available flat bar and square tubing sections for ready repair;
- it is flexible to absorb impact damage which might deform it but will not destroy its function;
- it is bolted in place for easy removal for repair or replacement;
- the continuous side handrails allow safer climbing by eliminating the need to remove one's hands to reach for the next rung; and
- the rungs are square tubing with the corners angled up for maximum grip.

Wiring for the signal light is routed through out of the battery well directly into the watertight bottom compartment using the existing square tube conduit system. It then passes up through the watertight compartment into a large diameter conduit. This conduit passes all the way up through the wet section of the superstructure to the top deck, where it is sealed by a watertight gland fitting. An additional conduit system is provided as a spare, or to fit cabling for a solar powered buoy in the future.

Threads for all bolted connections are provided by stainless steel threaded inserts which are easily replaced if the threads are damaged. This eliminates the need to replace bolting tabs or to enlarge thread diameters.

4.3 Bell Buoy Superstructure Design

The bell buoy superstructure design, shown in Figures 13 and 14, is a varying diameter structure with an octagonal cross section. The superstructure strength is derived from the stressed skin shell structure for the top and bottom sections, and from a series of tubular uprights through the centre section (where the bell is mounted).

Early conceptual designs for this approach were based on circular cross-section construction. This was modified to an octagonal cross section for the following reasons:

- the circular cross section could not accommodate radar reflectors large enough to have the desired radar cross section;
- the flat sides can be readily fabricated and repaired in most shops— fabricating the large diameter circular cones on the other hand requires specialized equipment; and
- a system of removable panels for testing purposes could be fitted more easily to the flat sides of the sound enclosure.

The superstructure is fitted to the buoy using a flanged base adaptor which is welded to the buoy hull. The bottom section of the superstructure is a watertight compartment constructed of 4.8 mm plate with 2 mm deck plating. The deck is stiffened at the mounting points for the uprights by an octagonal flat ring formed from 6 mm plate. An access panel is provided for wiring installation and maintenance.

The structural loadings are carried up through the sound signal compartment by eight vertical tubes, of 50 mm x 50 mm x 3 mm square cross section, placed at the apexes of the octagon cross section. The diameter of the superstructure at this point is expanded to enclose the bell and clappers. The expanded diameter is continued vertically up to the top of the sound chamber, to provide a mounting area for the radar reflectors.

Using steel enclosing panels, which are obviously not radar transparent, requires that the radar reflectors are incorporated into the outer skin of the superstructure. Eight panels with integral trihedral corner reflectors are fitted around the periphery of the superstructure, at the top of the sound chamber. These panels enclose the top of the sound chamber and provide the desired radar cross section.

The bottom of the sound chamber is enclosed by steel panels, to allow the maximum transmission of sound from the bell. An acoustically transparent fabric membrane over this section was considered. This was not done for a number of reasons:

- we were not able to find a suitable material which would stand up to five years exposure to a marine environment without requiring replacement;
- some form of structural backing (e.g. grating) would be required to provide the needed structural support for the fabric; and
- any solid panel material capable of lasting five years, although the panel may meet the acoustic insertion loss requirement, would reduce the sound transmission beyond that of a slotted panel.

Figure 13 Prototype Bell Buoy Superstructure

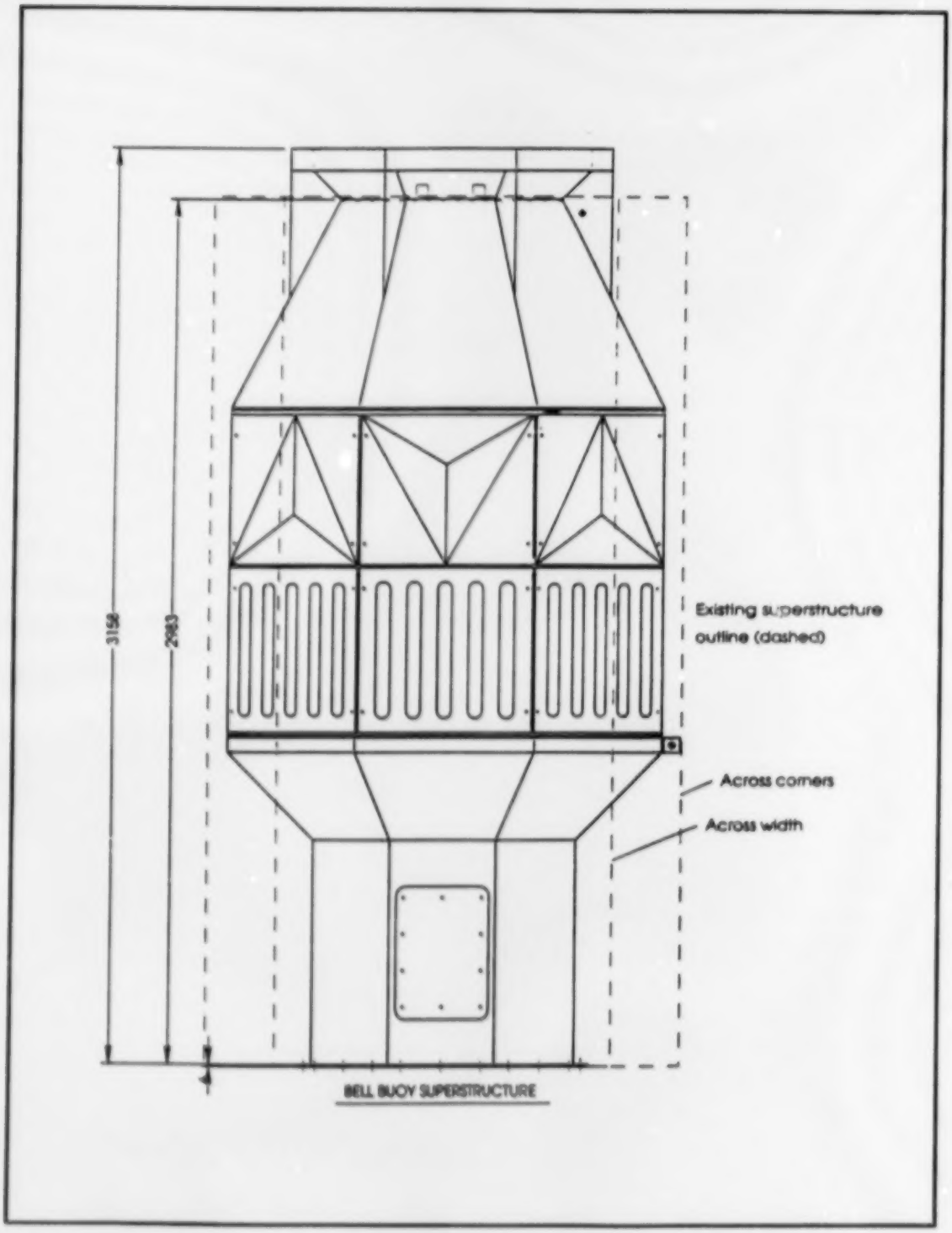


Figure 14 Bell Buoy Enclosed Superstructure Drawing

All of the panels are removable with bolted connections provided by replaceable threaded inserts, as for the whistle buoy. While not optimum from a service standpoint, this was done for experimental reasons. All of the panels can be removed and replaced with different designs for testing and experimentation. Also, the lower slotted panels can be removed or altered without affecting the radar characteristics, which are provided by the upper panels.

Figure 15 Prototype Bell Buoy Superstructure Showing Top Deck

One potential problem for the approach developed is that ice may build up inside the sound chamber, from water spray entering through the slotted panels. The outer panels may ice over during severe icing conditions, effectively fully enclosing the interior before significant accumulation can occur. This will be determined during the testing phase. While the sound chamber is out of the worst icing zone, it is much lower than that of the whistle buoy, and therefore will be more likely to ice up. Raising the bell is not desirable since the large mass of the bell affects metacentric height and therefore stability as it is raised. The existing design of bell and clappers has been maintained in the new superstructure.

The topmost section of the bell superstructure, shown in Figure 15, is a conical watertight compartment tapering in to a top deck. This section is formed from welded plate, 2 mm thick, stiffened with a stiffening ring at the bottom and gussets at the top. The top deck is 4.8 mm plate with a circular removable panel for internal access. A crash ring is formed from 75 mm x 75 mm x 3 mm square tube straight sections welded into an octagon shape. One section has been left out, where the ladder is located, for ease of access to the signal light.

Two working positions are envisioned. In the first, the light is serviced by standing on the ladder. The ladder, the guard frame, and the attachment gussets have been ergonomically designed to provide a secure and stable working position which allows access to the light with both hands free. Sitting on the deck or guard frame provides an alternative working position. This is not as spacious as the top deck of the whistle buoy superstructure, but there are a number of secure working positions possible.

As for the whistle buoy, the guard frame doubles as a strong pickup point for the initial recovery and stabilizing operation. The bell buoy uses all welded construction for the guard frame, as an alternative to the bolted attachment of the whistle buoy superstructure.

Figure 16 Buoy Superstructures During Transport to Newfoundland

Following completion the prototype superstructures were shipped to St. John's, Newfoundland for installation. Figure 16 shows the superstructures during transportation, and provides an effective size comparison. The buoys fitted with the new designs have been deployed in the following locations on the south coast of Newfoundland:

Whistle Buoy Superstructure

Buoy No.	QS2
Buoy Location	Southwest Rock

Bell Buoy Superstructure

Buoy No.	Q25
Buoy Location	Watch Rock

4.4 Enclosed Superstructure Summary Data

The following is a summary of the properties of the developed superstructures. Statistics for the existing superstructures are given for comparison.

Whistle Buoy Superstructure

	Existing Superstructure	New Buoy Superstructure
Height, mm	3220	2931 to top of main structure 3166 to top of guard frame
Width (across flats), mm	1157	1073
Width (across corners), mm	1636	1517
Daymark Area (m^2)*	3.6	3.2
Mass (kg)**	419	415
C.G., mm from bottom	1698	1575

Bell Buoy Superstructure

	Existing Superstructure	New Buoy Superstructure
Height, mm	3000	2990 to top of main structure 3165 to top of guard frame
Width (across flats), mm	1157	1500
Width (across corners), mm	1636	1624
Daymark Area (m^2)*	3.4	3.7
Mass (kg)**	444	540
C.G., mm from bottom	1689	1593

*Daymark area for the existing superstructures is outline area. In fact effective daymark area will be less than this due to the open frame construction.
**Ladders add about 25 kg to the mass of the superstructure.

5 CONCLUSIONS AND RECOMMENDATIONS

Two prototype enclosed superstructures have been developed for 2.9 m light and sound buoys, one bell and one whistle. Fully enclosed superstructures, which exhibit improved icing and reduced maintenance characteristics, have been previously developed for 1.8 m light buoys. Operational testing of the new superstructures for light and sound buoys is now underway, and similiar benefits are anticipated. The superstructure design has been developed to meet the functional requirements dictated by the role of the buoy as a floating aid to navigation. Operational constraints such as handling and service strongly influenced the design as well.

Final conclusions cannot be drawn until testing has been completed on the new superstructures. However, a number of significant results from the project may be reported:

- buoy structures should have a long design lifetime—buoy hull life exceeding fifty years is common;
- steel is the most appropriate structural material for retrofitting to existing 2.9 m steel buoy hulls;
- the primary design challenge in enclosed superstructure development is the balancing of tradeoffs due to conflicting requirements.

The completed prototypes possess the following attributes which are considered to be advantages over the existing designs:

- higher strength;
- lower mass, for the whistle buoy;
- reduced centre of gravity, improving stability;
- greater daymark area, improving visibility;
- watertight chambers in the base of the structures provide a dry area for future incorporation of electronic system and batteries for photovoltaic power system;
- better ice accretion properties, particularly for the whistle buoy prototype that has an outer cover of Surlyn™ plastic; and
- improved ergonomics while servicing the signal light.

These benefits do carry a cost, however. Disadvantages of the new superstructures when compared to the existing designs include:

- higher fabrication cost, which should be offset through longer life and reduced maintenance cost;

- vulnerability to damage of the handles and ladders that must be provided for service.

Early in the project, a number of esoteric concepts were proposed. Also, advanced materials were investigated. The expectation was that the developed prototypes would incorporate the latest technological advances. As the project advanced, very functional designs emerged, tempered by pragmatic decision-making and operational constraints. Some advanced materials have been incorporated, but for the most part the prototypes are composed of conventional technology, because the superstructures are one small part of an existing larger system. The considerations and constraints imposed by this system influenced the final result. Advanced materials and other technologies will be crucial for the next generation of navigation buoy technology.

The following recommendations are offered:

- Further development for maintenence should be directed towards coating improvements, e.g. arc spray metallizing or hot dip galvanizing, to increase the maintenance life cycle. Paint system are available for extended life, but chipping of paint from handling impacts remains a problem.

- The new superstructures should be tested initially for one icing season. Following this, the superstructures should be recovered, inspected, and their performance should be analyzed from the acquired data. Recommendations for improvement should be developed and implemented, and the buoys should be redeployed in time for the next icing season. It is quite possible that a unified design incorporating the most successful features from each prototype could result. This should be an extended deployment, and could possibly be done in a more exposed offshore location.

- The CCG should continue to investigate advanced materials and technologies for navigation buoy development. Development of the next generation of buoyage should be done from an overall system and operations perspective.

BIBLIOGRAPHY

Berteaux, Henri.O., Buoy Engineering, John Wiley and Sons, Toronto, Ontario, 1976.

Canadian Coast Guard Aids and Waterways, Navigational Buoy Design Manual.

Colvin, Thomas E., Steel Boat Building, Volume 2, International Marine Publishing Company, Camden, Maine, 1985, ISBN 0-87742-203-6.

Dick, R.A., Kalisiak, M. Experimentation with Various Methods of De-Icing and Anti-Icing for Ships, Transportation Development Centre, Montreal, Québec, June 1989, TP 9948E.

Klingel, Gilbert C., Boatbuilding With Steel, International Marine Publishing Publishing Company, Camden, Maine, 1973, ISBN 0-87742-029-7.

Tynes, Gordon A., Crick, D., The Evaluation of Advanced Industrial Materials for Use in Navigation Buoy Design, Advanced Materials Engineering Centre, Halifax, Nova Scotia, January 1991, TP 10774E.

Saeki, H., et al, The Coefficient of Friction Between Sea Ice and Various Materials Used in Offshore Structures, Journal of Energy Resources Technology, Volume 108, pp. 65-71, March 1986.

Skolnik, M.I., Radar Handbook, McGraw-Hill, New York.

Warren, Nigel., Metal Corrosion in Boats, International Marine Publishing Company, Camden, Maine, 1980, ISBN 0-87742-243-6.

APPENDIX A
Project Work Plan

PROJECT 90-57
TDC ENCLOSED SUPERSTRUCTURE

WORK PLAN

Introduction

The project has been structured into the following tasks:

Task 1.	Project Initiation
Task 2.	Review Previous Work
Task 3.	Develop Conceptual Designs
Task 4.	Refine Selected Design Concepts
Task 5.	Detailed Design and Prototype Fabrication
Task 6.	Deliver Prototype Superstructures
Task 7.	Final Report

Task 1. Project Initiation

Objective(s)

- To prepare a detailed work plan and master project schedule.
- Confirm the working arrangement with the Project Officer and the Technical Review Committee.
- Review the roles and responsibilities of all members of the project.

Activities

- Develop a detailed work plan including; activity schedule, cash flow projection, project management control and documentation procedures.
- Review and finalize the working arrangement.
- Conduct implementation meeting with the Project Officer.
- Finalize project management control and documentation procedures.

List of Deliverable(s)

- Detailed work plan (5 copies).

Task 2. Review Previous Work

Objective(s)

- To perform an in-depth review of recent Canadian Coast Guard work on designs for enclosed superstructure light buoys.

Activities

- Review documentation of recent tests of enclosed light buoy superstructures.
- Discuss superstructure technical matters.
- Discuss practical fabrication matters.
- Discuss buoy handling matters.
- Summarize task findings in a Requirements Summary document.

List of Deliverable(s)

- Requirements Summary (5 copies).

Task 3. Develop Conceptual Designs

Objective(s)

- To develop several concept designs for enclosed superstructure whistle and bell buoys for evaluation by the client.

Activities

- Develop design concepts.
- Produce concept documentation packages for presentation and discussion during client meeting.
- Meet with the customer to discuss design concepts and select most promising concepts.

List of Deliverable(s)

- Conceptual design documentation packages.
- Selections for advancement.

Task 4. Refine Selected Design Concepts

Objective(s)

- To select two designs for prototype manufacture and delivery. This selection would be made during a design review meeting, organized by TAVEL, to be held at CCG Headquarters in Ottawa.

Activities

- Refine the selected design concepts.
- Develop detail design engineering estimates.
- Develop manufacturing cost estimates.
- Produce interim report and forward to Scientific Authority.
- Organize and conduct design review meeting.

List of Deliverable(s)

- Interim Report (5 copies).
- Design Review Meeting.

Task 5. Detailed Design and Prototype Fabrication

Objective(s)

- To select the two designs for fabrication. Following approval of the selected designs by the Scientific Authority, detailed design packages will be completed for each design. This task may not proceed prior to receiving the GO-NO GO decision at the end of Task 4.

Acitivities

- Complete the detail design of the two selected designs.
- Prepare design packages for each superstructure design.
- Manufacture the two prototypes.

List of Deliverable(s)

- One completed prototype superstructure of each design.
- One completed design package for each design.

Task 6. Deliver Prototype Superstructures

Objective(s)

- To deliver the completed superstructure prototypes to CCG Newfoundland Region Headquarters in St. John's, Newfoundland for independent testing and evaluation.

Activities

- Prepare prototypes for shipment.
- Deliver prototypes to CCG Newfoundland Region Headquarters.
- Assist CCG technical staff to install superstructures to appropriate 2.9 meter buoy hull as required.
- Deliver copies of design packages.

List of Deliverable(s)

- Delivery of prototypes to St. John's, Newfoundland.
- Delivered design packages.

Task 7. Final Report

Objective(s)

- Produce the final report for the project.

Activities

- Prepare draft final report and Project Documentation Form. Deliver five copies of the draft final report to TDC immediately following the completion of the work. Also deliver five copies of the Publication Documentation Form (PDF) supplied by TDC. Following receipt of TDC comments and the translated text, prepare and deliver thirty copies of the final report to TDC. The final report is to be prepared in accordance with the **"TDC Publication Standards and Guidelines for Contractors (TP 929)"**. The report is to be prepared in English, with a summary in both English and French. Translation of the summary from English to French will be done by TDC.
- Prepare draft Report User Feedback Form. This form will be a one page double sided tear-out form to be included as the last page of the report. The draft of this form will be submitted as part of the draft final report and one copy of the finalized form shall be included as the last page of each final report delivered to TDC.

- Deliver draft materials to TDC.

- Prepare project presentation materials. Prior to submission of the final report, a slide and/or videotaped presentation on the work carried out and the results achieved will be made to TDC/CCG at a project conclusion meeting in Montreal or Ottawa.

- Prepare final report and Report User Feedback Form.

- Conduct project presentation in Montreal or Ottawa.

- Submit final report.

List of Deliverable(s)

- Draft final report (5 copies).
- Draft Report User Feedback form (5 copies).
- Publication Documentation Form.
- Copy of presentation materials.
- Final Report (30 copies).

APPENDIX B
Information on Surlyn Foam

THE
GILMAN
CORPORATION

P.O. BOX 68 · GILMAN, CONNECTICUT 06336 · 800 922-3626 · 203 887-7080 · FAX: 203 886-5402

January 8, 1990

Philip Huntley
TAVEL Limited
38 Fielding Avenue
Dartmouth
Nova Scotia, Canada B3B 1E4

Dear Mr. Huntley:

We have reviewed over our experience and that of our customers with ice exposure and our Softlite buoys. The consensus is that ice does not tend to form on the surface of Softlite. As evidence, we have verbal and written reports, video tapes and photos showing:

1. Only very thin or no skins of ice on Softlite buoys at times when nearby steel buoys have heavy accumulations of ice from spray (see attached excerpt from a report by the USCG R&D Center); and

2. Softlite buoys free of circumambient ice when nearby steel buoys are growing ice from the waterline (based on field reports from Arctic deployments of scientific buoys and photos from USCG and New York State showing effects of unanticipated freezing on seasonal placements).

In addition, our ski area impact barriers show a similar tendency to shed snow and ice build up; even those surrounding snow-making guns throwing hundreds of pounds of water into the air at freezing temperatures show no build up. Indeed, as the attached color brochure cover photo shows, the snow tends to melt away from the sides of the Softlite cylinders. Inside the hollow cylinders are always dry and free of snow and ice, even after a storm.

We have discussed this with Arctic scientists at Woods Hole, with experienced materials engineers at the US Coast Guard and among ourselves. There are three hypotheses:

A. The Softlite material absorbs heat from solar radiation or the atmosphere more efficiently than steel or other materials;

B. The Softlite material gives up heat more slowly than steel; it does not get colder than the water surrounding it even though the air temperature above may be much lower; and

C. The Softlite material's surface does not provide a good grip for ice formation.

We will be glad to work with you in testing these (or other) hypotheses by whatever methods and with whatever samples structures you think best. Please let us know how we can help.

Sincerely,

George M. Greider
Director, Marketing & Development

Introduction to Gilman Softlite® Ionomer Foam Products

The Gilman Corporation of Gilman, Connecticut is the leading custom manufacturer of ionomer foam products.

Ionomers are high grade thermoplastic polymers originally developed by I. E. DuPont de Nemours Company under the name Surlyn®. Ionomer resin can be manufactured into solid plastic, flexible film or foam. Foamed ionomer offers low weight, low density, toughness, durability, high energy absorption, excellent thermal and acoustical insulation, great resistance to environmental agents, such as radiation, salt, fuels, chemicals, wave action, etc. in a form that is soft, flexible, non-abrasive and which can be fabricated into structures of almost any size or shape.

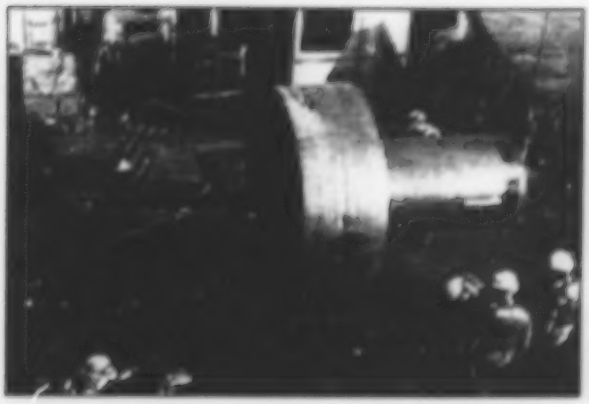
Gilman, Connecticut has been a manufacturing site since the eighteenth century. After the Second World War, the Gilman Corporation began working with plastics and rapidly became a leader in plastics extrusion technology. The Gilman Corporation has been producing ionomer foam since 1969 under the name Softlite Ionomer Foam. All Softlite products are created using the same basic extrusion and fabrication technology developed by the Gilman Corporation.

Softlite ionomer has the unique ability to link ionically to neighboring molecular chains with the same bond as the polymer chain itself. Extruded as a continuous sheet of foam, Softlite has a thick-walled, closed cell structure. During the foaming process, uniform pigments, ultraviolet stabilizers and antioxidants are integrated into the cell structures.

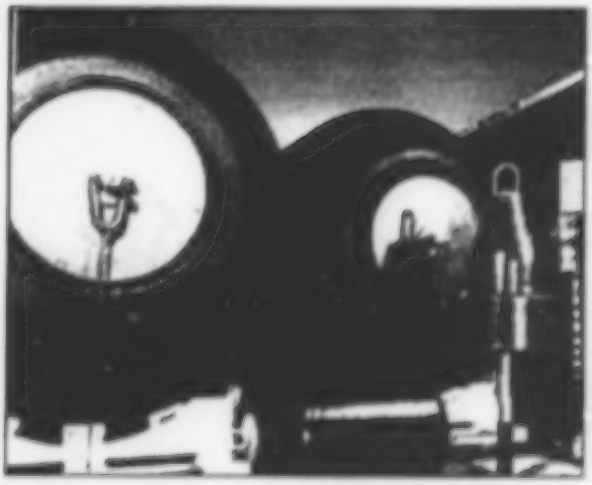
Extruded, ionically cross-linked ionomer foams are considered the toughest, most durable, flexible low density, closed-cell foams on the market.

The extruded foam can be built up as flat sheets or as concentrically rolled cylinders using heat and pressure to create structured homogeneous masses of tough, universally pigmented, closed-cell foam with exceptional integrity.

This Softlite foam mass can be shaped to any exterior contour by heat-cutting. All surfaces can be densified by heat and pressure to form an extremely strong, abrasion resistant, integral, outer skin. The resultant structure offers superior strength and unsurpassed structural integrity.



By this technology, Gilman manufactures navigational aids for the U.S. and Canadian Coast Guard, nuclear weapon floats and fenders for the U.S.



Navy, scientific platforms for research groups all over the world including Woods Hole Oceanographic Institution, Battelle Ocean Sciences, National Data Buoy Center. Softlite impact barriers and lift seat cushions are used by ski areas world-

wide. Softlite seals provide inert, vapor-proof barriers for floating covers on large chemical storage tanks. Softlite padding and covers are used extensively by the pool and spa industry. Gilman Twist-Tie® pipe insulation and Soft-Lite flooring are used in residential, commercial and industrial construction and retrofitting. Other Softlite products have proven uniquely valuable for special uses in irrigation, athletic equipment, mining and construction.

As a custom manufacturer, modifications or novel designs are always available from Gilman Corporation. Just call us and ask. 1-800-622-3626

APPENDIX C

Letter from General Composite Technology

TAVEL

General Composite Technology

February 26, 1991

Mr. Ronald Cunningham, P.Eng.
Director - Development Engineering
Tavel Limited
38 Fielding Avenue
Dartmouth, NS B3B 1E4

Dear Mr. Cunningham:

Thank you for taking the time to visit GCT on February 18th to discuss your possible uses for composites in Tavel's Reduced Maintenance Buoy Contract. I believe that your decision to go to an essentially all steel, enclosed superstructure design is very sound, given the emphasis on retrofittable potential in your contract.

I believe, as we discussed, that a newer generation of buoys with an all composite/plastic structure offers major potential benefits to the Canadian Coast Guard. Specifically, as has been proven in Norway by Selco and in Britain and the North Sea by Balmoral Warfield & others, these all composite buoys offer:

- Zero corrosion related maintenance requirement;
- Enhanced resistance to ice build-up;
- Increased potential for visibility through long-life color stability and higher allowable light tower heights;
- Dramatically reduced weight with consequent savings in mooring weight, and increased ease of deployment and positioning.

Depending on the numbers, these new generation buoys could be cost effectively made by either lay-up techniques or by filament winding.

The ***marine composites alliance***, of which GCT is a member, would be very interested in cooperating with Tavel on any possible related projects. In particular, ***mca*** member Fleet Technology is very knowledgeable of the Canadian marine environment's effects on composite materials and FRE Composites is Canada's most capable and cost effective filament winding design and fabrication firm.

The Advanced Materials Engineering Centre has been conducting a study of Composites for Buoys for some time now. Perhaps, when the results of this study are made available, it might be worthwhile further discussing this point.

Should any of Tavel's other projects have a need for composites material input, please feel free to contact me.

Regards,

J. Gordon Murphy
Vice President

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General Composite Technology Ltd., P.O. Box 8, Unit M, Halifax, Nova Scotia, B3J 2L4 Tel: (902) 425-1091 Fax: (902) 429-6071
American Composite Technology Inc., 336 Northern Ave., Boston, MA, USA, 02210 Tel: (617) 439-4142 Fax: (617) 439-4892
Thor Dahl Inc., 660 Third Avenue, Suite 3100, New York, NY, USA, 10022 Tel: (212) 755-7812 Fax: (212) 755-7815

Reply to: ☒ ☐ ☐